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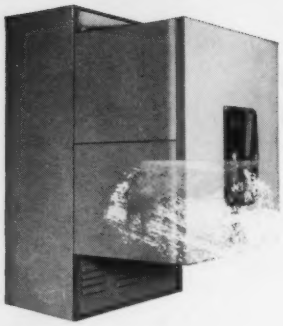

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THE COVER

RESEARCHERS using latest advances in chemistry are now probing the fuel cell as an efficient energy converter. Photograph was taken by light of two 15-watt light bulbs powered by the cell.

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ELECTRICAL REVIEW

Vol. XXIII No. 3

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CONTENTS

What About 5/8% Feeder Voltage Regulation?..... 4
I. W. Best and H. C. Brem

Evaluating High Temperature Liquid Pumps..... 7
A. F. Erwin

Designers' Models . . . The Modern Engineer's Tool.. 12
W. C. Frazier

New Light on Fuel Cells..... 14
J. P. Manion

Applying Correlation Analysis to Engineering Problems..... 18
George Shombert

Is "Patent Knowledge" One of Your Working Assets? 23
H. L. Swenson

Good Management with "Completed Work"..... 25
G. E. Feldman

New Capacitor Trip Operates on Low Voltage..... 29
Carl Feldman

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What About 5/8% Feeder Voltage Regulation?

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Allis-Chalmers Mfg. Co.

THE 5/8% STEP REGULATOR is easily preset by adjusting a single knob to the desired operating voltage. **(FIGURE 1)**

Closer voltage regulation with a narrower voltage band means increased revenue for the utility.

VOLTAGE REGULATION as near the optimum as possible will increase distribution system efficiency. In the past some utilities based the justification of capital expenditures for voltage regulators on intolerable voltage conditions, not on purely economic advantages of automatic regulation. However, many utilities conducted extensive studies, over a period of years, to prove the economic value of better regulation. Today, most utilities recognize the value of close regulation.[1, 2]

Better regulation means better operation

When voltage conditions improve or approach their best operating point, more kilowatt consumption results. This means that more revenue can be realized by maintaining the voltage as close to the desired level as possible.

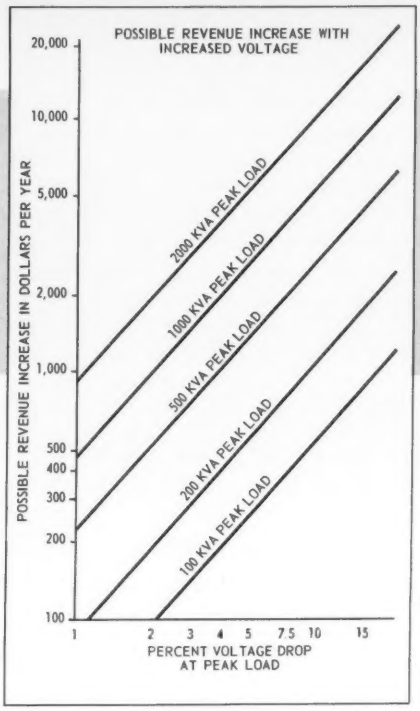
When the power user receives proper voltage, he gets full advantage of his electrical equipment. The domestic user realizes more efficient heating and lighting, while the industrial user receives efficient equipment performance. The power user who is satisfied with his electrical machinery will consider his future needs in terms of increased use of electric power.

The revenue increase that can be realized by maintaining a voltage as close to the optimum as possible is shown in Figure 2. For example, correction of a 3% voltage drop at a 1000-kva peak load can mean about $1500 revenue increase a year.

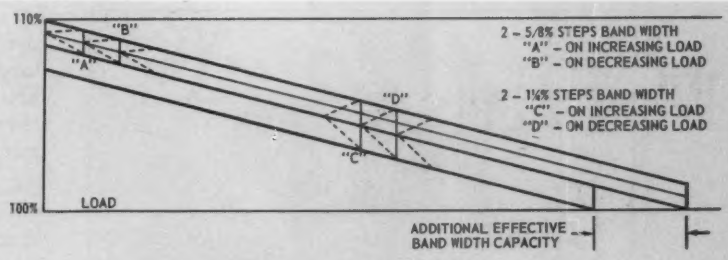
Distribution equipment such as transformers and regulators operate more efficiently when the voltage is kept near design values. Too high an excitation voltage will increase transformer core losses and cause excess heating and accelerated insulation deterioration. Too low a voltage, while not detrimental to a distribution transformer, will cause it to operate less efficiently, since it is not operating at its full capacity. Equipment cost is based on capacity and is designed to system requirements but must be used at those requirements for full efficiency.

Since a voltage regulator in a system keeps the voltage to within desired limits, the narrower the limits, the better the regulation, with the voltage maintained as close as possible to the 120-volt standard or 100% utilization. A 5/8% step regulator can hold the voltage between 119¼ and 120¾ volts on a two-step band width basis, while a 1¼% step regulator will hold the voltage between 118½ and 121½ volts on the same two-step band width basis. Smaller band width is possible but may require more operations. For a reasonable number of operations the band width should be two steps. From the above relationships it can be seen that the 5/8% step regulator will maintain the voltage within narrower limits. The range through which the regulator operates is the effective band width. Figure 3 illustrates how each type of regulator stabilizes the voltage. As a result, effective range of regulation of the 5/8% regulator extends further than the range of the 1¼% step unit.

The capacity of a line to distribute maximum kilowatt-hours is dependent on the voltage regulation and the band width of that regulation. With the increase in line capacity made possible with 5/8% step regulation, either the load on the regulated line can be increased or the length of line increased to serve additional users. The increase in line capacity on existing lines when the band width of two 5/8% steps is used instead of two 1¼% steps is shown in Figure 4. At a 10% voltage tolerance, about 17% additional kilowatt-hours can be supplied from this same line. The increase in line capacity by added feeder length with 5/8% steps compared to 1¼% steps is shown in Figure 5. At a 10% voltage tolerance about 8% more feeder length can be added. This is clearly shown in additional feeder length in our comparison of operating ranges of the two-step band width shown in Figure 3.



REVENUE RISES WITH CORRECTED INCREASE in percent voltage drop with ⅝% step regulators connected in the system. **(FIGURE 2)**



FIVE-EIGHTHS PERCENT step regulation maintains voltage closer to desired level than does 1¼% step regulation. **(FIGURE 3)**

Narrower band width results calculated

A distribution system has a certain voltage tolerance ($V_{max} - V_{min}$) which has been set between the highest voltage allowable on the first distribution transformer and the lowest voltage allowable on the last distribution transformer. Figure 6*a* shows a regulator voltage band width, BW_1, and Figure 6*b* shows a narrower band width, BW_2. Voltage tolerance, levels, and feeder lengths are the same. How much more load can the system in Figure 6*b* carry above the capacity of Figure 6*a*? Since the band width (BW) plus the voltage drop (IZ) in each system must equal the voltage tolerance, their sums are equal.

$$BW_1 + I_1Z_1 = BW_2 + I_2Z_2 \qquad (1)$$

Since $D_1 = D_2$ then $Z_1 = Z_2$

$$I_2 - I_1 = \frac{BW_1 - BW_2}{Z_1} \qquad (2)$$

$$BW_1 + I_1Z_1 = V_{max} - V_{min} \qquad (3)$$

Dividing Eq. (2) by Eq. (3) the result is:

$$\frac{I_2 - I_1}{I_1} = \frac{BW_1 - BW_2}{V_{max} - V_{min} - BW_1} \qquad (4)$$

$$\text{Percent load increase} = \frac{(\text{Original band width} - \text{new band width}) \times 100}{\text{Voltage tolerance} - \text{original band width}} \qquad (5)$$

The load increase can be appreciable. Consider a system with a voltage tolerance of 10%. When two ⅝% steps are used in place of two 1¼% steps, the load increase equals $\frac{2.5 - 1.25}{10 - 2.5} \times 100 = \frac{1.25}{7.5} \times 100 = 16.6\%$.

The curve in Figure 4 shows the increased loads possible when ⅝% steps are used.

Feeder loads can increase with greater line length as well as with increased line capacity. While again referring to Figure 6*b*, let D_2 increase, picking up additional distributed load until the voltage reaches the minimum allowable V_{min}. How much can D_2 increase?

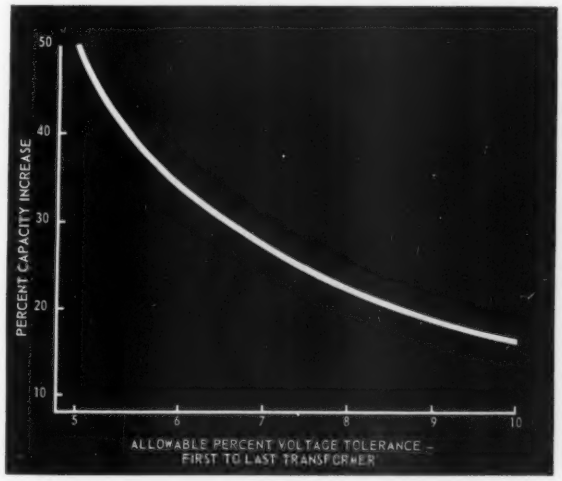
Assuming an equally distributed load, the current I_1 is proportional to the distance D_1 as is the impedance Z_1, so that the voltage drop I_1Z_1 is proportional to the distance D_1 squared. The voltage drop I_2Z_2 is also proportional to distance D_2 squared.

$$\frac{D_2^2}{D_1^2} = \frac{I_2Z_2}{I_1Z_1} = \frac{V_{max} - V_{min} - BW_2}{V_{max} - V_{min} - BW_1} \qquad (6)$$

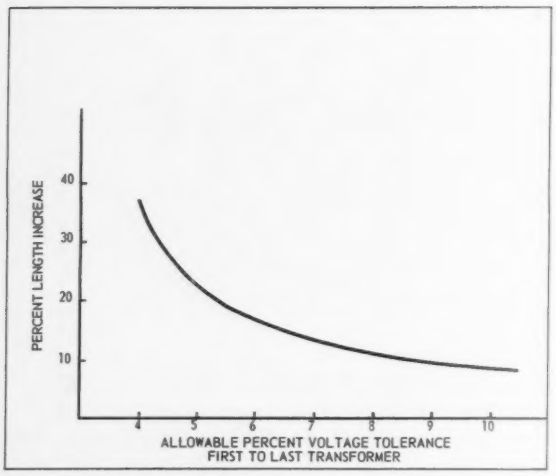
$$\frac{D_2}{D_1} = \sqrt{\frac{V_{max} - V_{min} - BW_2}{V_{max} - V_{min} - BW_1}} \qquad (7)$$

$$\frac{D_2 - D_1}{D_1} = \sqrt{\frac{V_{max} - V_{min} - BW_2}{V_{max} - V_{min} - BW_1}} - 1 \qquad (8)$$

$$\text{Percent increase in feeder length} = \left[\sqrt{\frac{\text{Voltage tolerance} - \text{new band width}}{\text{Voltage tolerance} - \text{old band width}}} - 1\right] \times 100 \qquad (9)$$



FEEDER CAPACITY is increased when band width of two ⅝% steps is used instead of band width of two 1¼% steps. **(FIGURE 4)**



FEEDER LINES can be lengthened when the voltage band width is narrowed to two ⅝% steps in place of two 1¼% steps. **(FIGURE 5)**

For example, with a voltage tolerance of 10%, a new band width of 1.25% with two ⅝% steps and old band width of 2.5% with two 1¼% steps, the increase in feeder length will be:

$$\sqrt{\frac{10-1.25}{10-2.5}}-1\times 100=8\%$$

The curve in Figure 5 shows the added feeder length possible when ⅝% regulators are used at various voltage tolerances.

Narrower band width gives better regulation

The band width setting possible on a voltage regulator is determined by the size of the regulator step. The smallest theoretical band width would be slightly larger than one step, since a smaller setting would cause hunting, which is impractical. Any small change in excitation voltage could cause hunting, so the practical minimum band width is approximately two steps, with narrower steps available for the ⅝% step regulator. The narrower band width means an increase in the amount of load that can be carried on a given system or an increase in the usable length of the line. Refer to Figures 4 and 5.

The economic value of any equipment is determined to a large extent by its cost of operation. In the early designs of some manufacturers of step voltage regulators the operating mechanisms were slow and current-carrying contacts had to be changed at intervals of approximately 100,000 operations. Contact life has been greatly extended since the first spring-operated quick-break contact mechanism was designed in the early 1930's. Many available records show that main contacts have operated well over 2,000,000 times and remain in good operating condition. Such excellent operating records are due to several factors, such as size of step, current carried, material used for the contact, size of the contact, and the speed of contact operation. With the use of the smaller ⅝% step there is less contact deterioration per step than with a 1¼% step because the kva of interruption is less. Smaller ⅝% step regulators have an excellent service record with reference to low oil deterioration. The ⅝% step mechanisms have operated in the same oil as the transformer coils for over 20 years. There is no evidence that any voltage failures resulted from operation of the mechanism and coil in the same oil.

Closer voltage regulation made possible with ⅝% steps has many definite advantages to a utility. Utility revenue increases and system equipment operates more efficiently. Increased loading or added feeder length is also possible with narrower ⅝% regulators on an existing line. Resultant minimum maintenance rounds out the picture of a well-designed system when ⅝% regulators are used. Today ⅝% step regulation has been widely accepted as the standard for both power and distribution levels of system operation.

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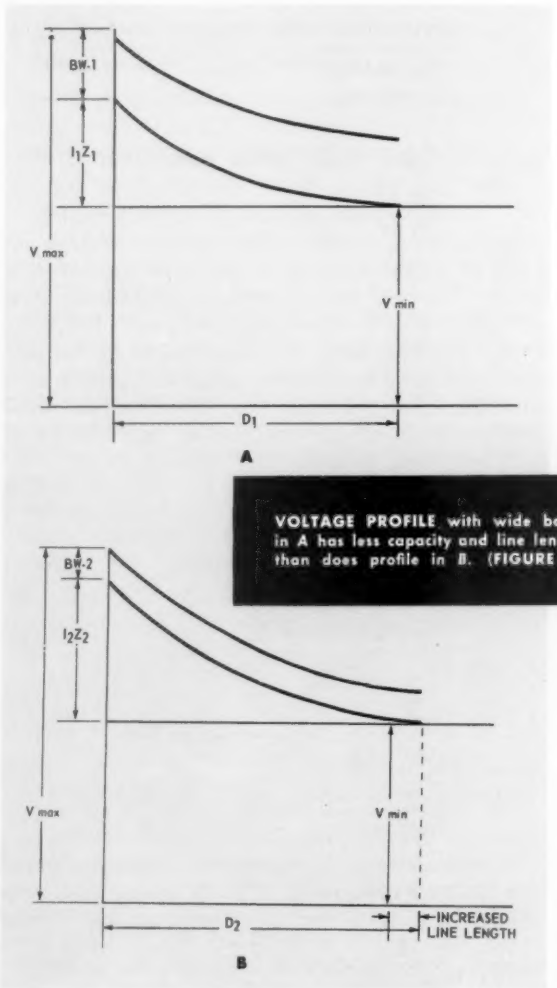

VOLTAGE PROFILE with wide band in A has less capacity and line length than does profile in B. **(FIGURE 6)**

EVALUATING HIGH TEMPERATURE LIQUID PUMPS

by **A. F. ERWIN**
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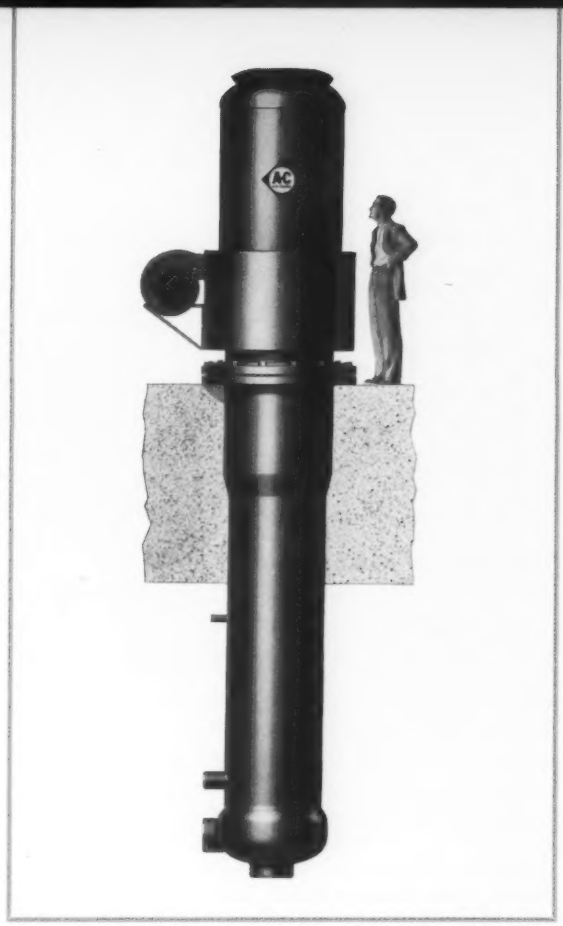
High temperature liquid metals in nuclear plants require specially designed pumps. Actual system pump requirements are discussed.

THE LIQUID METAL PUMP REQUIREMENTS for four major nuclear power reactor installations have been crystallized recently, and the coolant system conditions for two additional new high temperature liquid reactor plants have been established.

The specifications for these pump applications, and the types of equipment selected, indicate the present trends in nuclear plant design and in high temperature liquid pump development.

Prototypes selected for Sodium-Graphite Reactor

The selection of two types of pumps for extensive testing as prototype primary and secondary coolant circulating units for the 75-Mw Sodium-Graphite Reactor (SGR), to be located at Hallam, Nebraska, has been announced. This plant will supply electricity for use in Nebraska. This sodium-graphite reactor plant will be similar to the 6-Mw Sodium Reactor Experiment (SRE) now being put into operation at Santa Susana, California. The SRE pilot plant pumps are relatively conventional centrifugal pumps supplied with a refrigerated shaft seal that confines the sodium in the pump, at low differential pressure, by freezing the sodium into a waxy solid in the annular shaft sleeve. It is necessary to maintain an inert gas atmosphere above the seal, with gas that is completely oxygen free and moisture free to protect the seal from damage by oxidation of the sodium. A dependable gas seal and gas enclosure are required above the pump. It is also necessary to provide a lubricated bearing near the seal to control vibration and possible misalignment problems.



LARGE *ELECTROMETIC* liquid metal pump has integral, variable-speed drive and provides built-in radiation shielding. **(FIGURE 1)**

The frozen seal unit permits using a conventional drive motor and variable-speed drive above the gas seal. This arrangement has shown promise in the pilot operation, and one pump of this type has been ordered for further development as one of the prototype test units for the SGR project.

A parallel pump development for Argonne National Laboratory's Experimental Breeder Reactor II has recently provided extensive test experience on a new type hermetically sealed pump unit. The new design also uses conventional centrifugal pumps, motors and standard variable-speed drives, but eliminates the need for the liquid seal and gas seal by confining the inert gas inside the motor. Modifications to the motor terminal box and housing joints to secure gas tightness are relatively straightforward when applied to the totally enclosed fan-cooled tube-type motor. The integral heat exchanger of this motor cools the inert gas held in the motor above the pump tank to the normal motor operating temperature ranges. The selection of silicone rubber insulation, vulcanized around the entire winding, protects the motor under all specified conditions. This design has also been selected as a prototype primary and secondary test pump to confirm its suitability for the special conditions of the Hallam nuclear facility.

The specifications for the Hallam pumps call for a rating of 7200 gpm at 150-ft head of 1000 F sodium. The radioactivity level of the sodium requires shielding built

into the primary pump equivalent to seven feet of concrete. The liquid-containing elements must be designed to resist thermal stresses resulting from rapid changes of sodium temperature over several hundred degrees, under reactor scram conditions. The pump must have low resistance to thermal circulation when its drive motor is not operating. The system's thermal head conditions, shielding requirements and heat exchanger location require an unusually long and large diameter drive shaft to permit locating the motor above the shielding. The pump design resulting from these requirements and restrictions is the hermetically sealed, totally enclosed fan-cooled motor-pump unit illustrated in Figure 1. The freeze-seal prototype pump arrangement is shown schematically in Fig. 2.

Two types of pumps specified

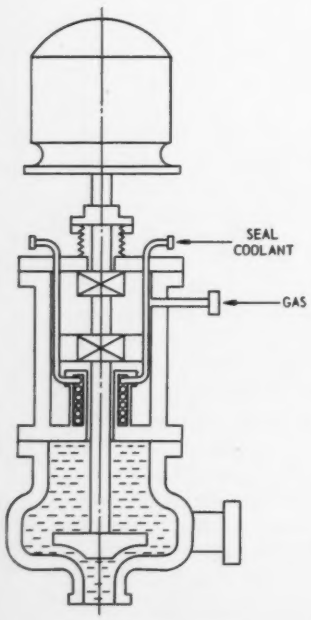
The prototype tests conducted by Argonne National Laboratory for the Experimental Breeder Reactor Project (EBR II) included tests of the hermetically sealed gas-filled motor-pump, and also of a 5000-gpm electromagnetic pump of the alternating current linear type. The system conditions for the 20-Mw EBR II plant required that the secondary circuit pump be capable of operating at extremely low flows, by varying pump speed or power supply, and be capable of providing reverse flow at low capacity. It was also considered essential to locate the secondary pump at the low point of the circuit. These factors, which were required by the experimental characteristics of this plant, would favor the selection of the electromagnetic pump for the EBR II secondary circuit in spite of its low efficiency. The basic design of this electromagnetic pump is shown in Figure 3.

Problems that have been associated with electromagnetic pumps include the need for thin-walled ducts containing the high temperature liquid metal to reduce electrical losses. The windings and electrical insulation must be close to the high temperature liquid in these designs. This makes it necessary to locate the coolant liquid coils close to the metal ducts. Thin-walled expansion joints are required and bulky secondary enclosures must be provided to contain the radioactive liquid in the event of failure of any of these critical elements. Electromagnetic pumps have inherently poor efficiency and require external power supplies, such as motor-generator sets, to obtain variable flow.

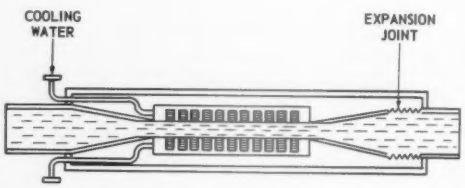
The EBR II primary pump specifications call for installation of the pumps within the reactor shielding, with the pump casing submerged in the liquid metal in which the reactor core is immersed. A long drive shaft is required that extends up through the shielding so that the drive motor can be located outside the reactor shield. A gas-impervious motor housing completes the hermetic sealing of this pump.

Two primary pumps are required. They will operate in parallel, and must be capable of single pump operation without check valves and without overspeed damage when the idle pump is turbining on the circuit.

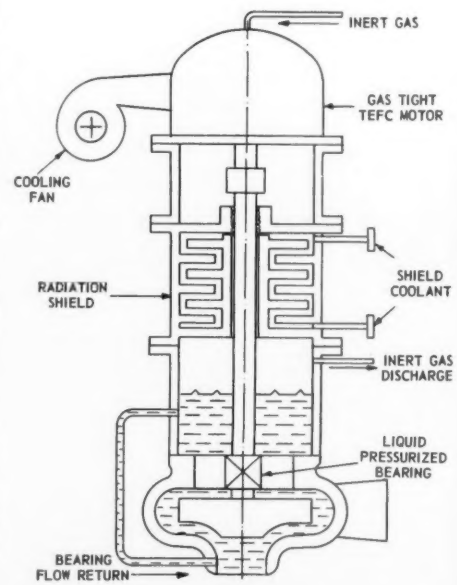
The EBR II primary pump rating is 4500 gpm against 185-ft head of 700 F sodium. Variable flow from 100 percent to 10 percent is achieved by motor speed variation with a variable frequency power supply.



FREEZE-SEAL pump design can use a standard flange-mounted motor drive. **(FIGURE 2)**



ALTERNATING CURRENT linear electromagnetic pump uses magnetic induction to move the high temperature liquid metal through the unit. **(FIG. 3)**



HERMETICALLY enclosed motor-pump utilizes industrially proven components for maximum reliability. **(FIGURE 4)**

This pump installation arrangement offers a number of advantages. These are: dependable containment of the radioactive primary sodium circuit, pumps, reactor and heat exchanger in a single container; reduction of pipe expansion and thermal stresses in the primary circuit to a minimum; simplified installation and removal of all components without welding or cutting pipe connections; reduced circuit friction for thermal circulation; and simplified filling, draining, pumping and level control in a single liquid containment vessel.

The design of the hermetically enclosed pump to meet the EBR II primary conditions is shown schematically in Figure 4.

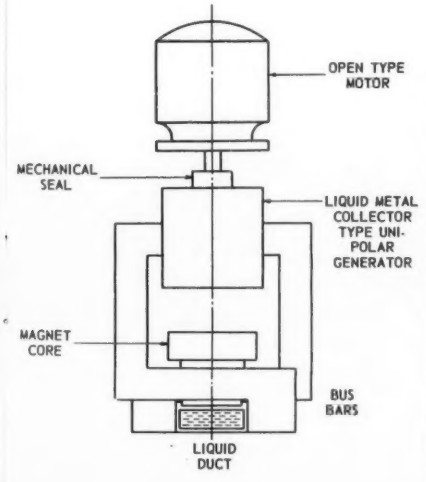
An electromagnetic pump of the dc Faraday type, in Figure 5, with unipolar generator power supply was also developed for the EBR II primary pump conditions.

Fast Breeder Reactor plant pumps selected

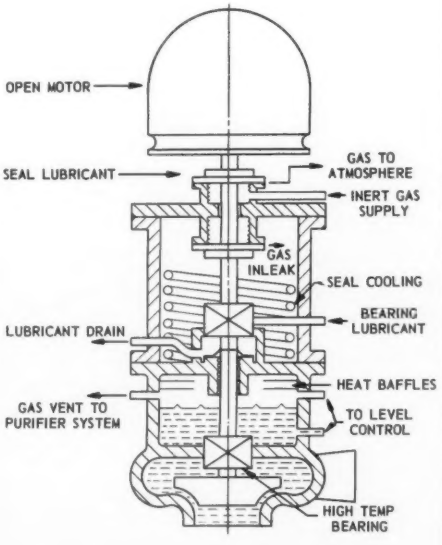
The 100-Mw Enrico Fermi Fast Breeder Reactor plant (EFFBR), developed by Atomic Power Development Associates and now being built by the Power Reactor Development Company at Monroe, Michigan, will be similar in many respects to the Experimental Breeder Reactors, EBR I and EBR II, developed by Argonne National Laboratory. However, the three primary pump circuits and heat exchangers are isolated from the reactor containment vessel, but are within the primary shielding. Each primary pump is installed in an individual tank approximately 6 feet in diameter and 16 feet high, in which an inert gas atmosphere will be held above the liquid level by a series of mechanical shaft seals. They are arranged so that clean gas is introduced between the seals at pressure differentials sufficient to assure that gas leakage to atmosphere and into the reactor circuit will be restricted to the clean gas supplied. The rating of these primary pumps is 10,000 gpm at 225-ft head of 550 F sodium.

Problems associated with mechanical seals for liquid metal pumps include: cooling and lubricating the seals; maintaining precise alignment and freedom from vibration; holding a high vacuum while purging and filling the system, combined with the capability to withstand high pressure surges in emergencies without loss of radioactive gas and sodium. The cost of the inert gas supply, including assuring an uninterrupted supply of dehydrated oxygen-free gas at all times and the cost of replacement of gas wasted to atmosphere, is an additional problem. Maintenance cost and outage time evaluation are difficult to determine without extensive test experience.

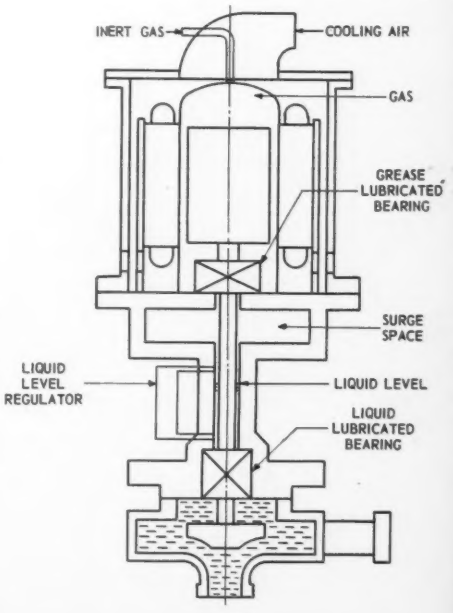
The mechanically sealed liquid metal pump is lower in first cost than hermetically sealed types because it permits using standard open motors and speed changers. The pump will require the least development work if conventional seals can be adapted for liquid metal service. A mechanically sealed type has also been selected for three secondary circuit pumps of the Enrico Fermi Fast Breeder Reactor, rated 12,200 gpm at 93-ft head of 520 F sodium. Although an evaluation of the many factors affecting selection of these pumps has indicated that superior depend-



DC FARADAY electromagnetic pump with a unipolar generator power supply was primarily developed for reactor primary pump conditions. **(FIG. 5)**



MECHANICALLY SEALED pump can reduce the initial cost of nuclear plants if the seal maintenance problems can be satisfactorily overcome. **(FIG. 6)**



TYPICAL GAS-FILLED CANNED MOTOR PUMP is designed to handle high melting point liquid metals used in nuclear power plants. **(FIGURE 7)**

ability can be obtained with hermetically sealed types, the experimental nature of this plant and the emphasis on minimum initial cost were felt to justify the selection of a mechanically sealed liquid metal pump. A typical double mechanical seal pump arrangement is shown in Figure 6.

Liquid Metal Fuel Reactor Experiment pump requirements resolved

The Liquid Metal Fuel Reactor Experiment project (LMFRE) is intended to demonstrate the feasibility of the high temperature reactor type developed by Brookhaven National Laboratory, in which the metallic fuel is dissolved in molten bismuth which acts also as the primary coolant fluid. The reactor is an experimental reactor which will be operated only as a heat source, to provide data and develop a system for extension to full scale power plant ratings. Two pumps are specified for the primary bismuth-uranium fuel-coolant circuit, both rated 720 gpm at 20 ft of 1000 F *Bi-U* alloy. Variable flow by pump speed control is required over 100 percent to 10 percent of rating.

Pumps considered for this application include mechanically sealed pumps, electromagnetic pumps, gas-filled canned motor pumps and externally enclosed motor pumps. The selection of the pump for Liquid Metal Fueled Reactor Experiment has not been made. Figure 7 shows schematically an applicable pump arrangement.

Alaskan nuclear power plant design proceeding

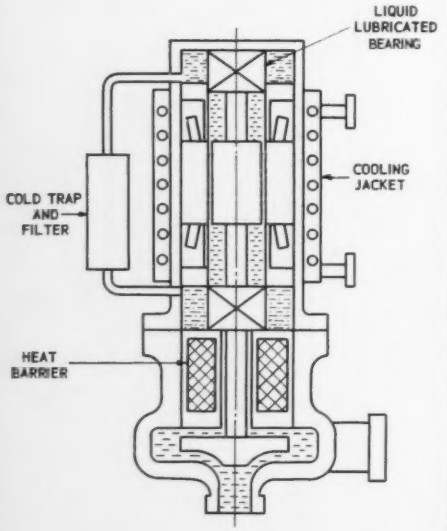
A 10-Mw sodium-cooled, deuterium-moderated reactor (SDR) will be built by Nuclear Development Corporation of America for installation at Anchorage, Alaska. Preliminary rating for the primary coolant pump is 5400 gpm at 207-ft head of 950 F sodium. The secondary coolant pump rating is 3600 gpm at 132-ft head of 600 F sodium. Auxiliary pumps rated 540 gpm and 360 gpm at 70-ft head will also be required for the primary and secondary circuits. The pump types for this plant have not been selected. For the auxiliary pumps, the canned motor pump shown in Figure 8 is one type that could be applied.

Other electromagnetic pump designs have been tested successfully on high temperature liquid metals in this capacity range. Two of these pumps are shown schematically in Figures 9 and 10.

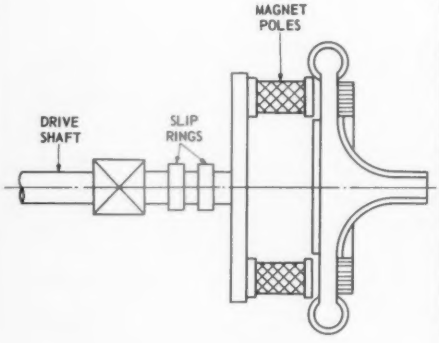
Molten salt power reactor design proposed

A proposed 240-Mw central station molten salt power reactor of the homogeneous type is being developed at Oak Ridge National Laboratory. The reactor will require large capacity pumps for fused salts and liquid metals at temperatures up to 1200 F. The system requires the primary coolant pump to be installed in the highly radioactive zone adjacent to the reactor.

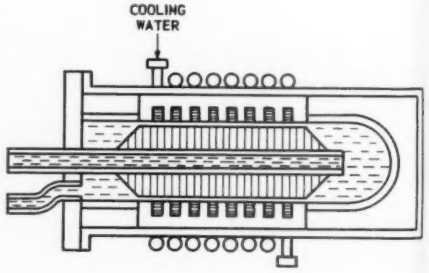
Initial studies of pumps for extreme conditions indicate that special pump and drive designs will be required to secure dependable operation. One configuration under consideration is a centrifugal pump driven by a close-coupled hydraulic turbine energized by a compatible secondary circuit fluid. The schematic arrangement of this turbo-pump is shown in Figure 11.



LIQUID-FILLED canned motor pump is suitable for low melting point liquid metals. **(FIGURE 8)**



ELECTROMAGNETIC CENTRIFUGAL PUMP can be coupled to any drive. **(FIGURE 9)**



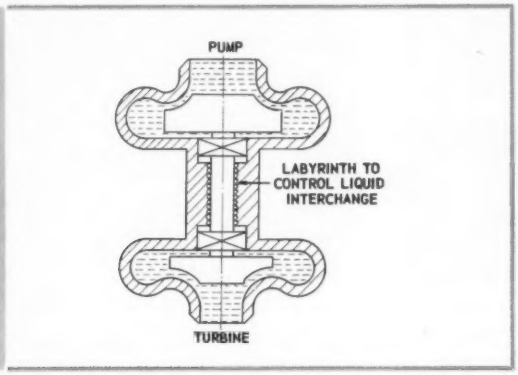
EINSTEIN-SZILARD pump eliminates expansion joints and simplifies field replacement. **(FIG. 10)**

Many factors must be considered

A typical evaluation comparison of high temperature pump types for a reactor power plant is summarized in Figure 12. It will be noted that the obvious advantages of hermetically sealed construction in the canned motor pumps, and eliminating moving parts in the electromagnetic pumps, are offset by quite a few less obvious disadvantages that are fundamental to their present designs. Some of these disadvantages may cause concern relative to their long-range dependability in high temperature liquid pump applications.

A similar list of critical requirements for mechanically sealed pumps must be fulfilled at all times if the seals are to operate for a reasonable length of time between replacements. The background of tests on seals for liquid metal pumps has been generally unsatisfactory.

These critical factors are difficult to evaluate against first cost of equipment, since the evaluation depends upon the unpredictable number and duration of failures, the ability to indicate wear and to schedule maintenance, the loss resulting from outage time, and the cost complications of maintenance in the specific installation under consideration. It appears evident that the prevention of just a few occurrences of unscheduled maintenance with corresponding outage time in a nuclear plant will justify a considerable increase in the first cost of nuclear pumps.



TURBO-PUMP, circulating primary coolant with turbine drive, permits drive motor to be located separately from the radioactive area. **(FIG. 11)**

Item	Factor	Hermetically Sealed TEFC Motor-Pump	Canned Motor Pump	Electro-Magnetic Pump	Mechanically Sealed Pump
1.	Provides complete hermetic sealing of entire unit	Yes	Yes	Yes	No
2.	Provides dependable containment of maximum pressure surge under all conditions	Yes	Yes	Yes	No
3.	All elements capable of withstanding high vacuum, as required in purging and filling system, without collapse of thin ducts, or seal leakage	Yes	No	No	No
4.	Eliminates containment of liquid metal in thin-walled ducts or cans	Yes	No	No	Yes
5.	Eliminates thin-walled expansion joints containing liquid metal or gas	Yes	Yes	No	Yes
6.	Provides proved satisfactory operating record of 8000 hours test on large capacity prototype pump	Yes	No	No	No
7.	Eliminates liquid coolant in close proximity to sodium containment	Yes	No	No	No
8.	Eliminates seal lubricant supply and recovery system	Yes	Yes	Yes	No
9.	Eliminates requirement for multiple bearings to protect seals from vibration and misalignment	Yes	Yes	Yes	No
10.	Provides integral hermetically sealed speed changer for flow control	Yes	No	No	No
11.	Eliminates cold-trap and filter requirement and servicing	Yes	No	Yes	Yes
12.	Minimum maintenance record provides assurance of dependability	Yes	Yes	Yes	No
13.	Design provides indicators to permit scheduled maintenance	Yes	No	No	No
14.	Design provides accessibility for economical servicing	Yes	No	No	Yes
15.	Design provides protected high temperature bearing, resistant to foreign material in liquid	Yes	No	Not Req'd	No
16.	Design provides high overall efficiency	Yes	No	No	Yes
17.	Design provides for variable speed with standard power supply	Yes	No	No	Yes
18.	Design utilizes heavy duty industrial components	Yes	No	No	No
19.	Integrated unit design coordinates all components under single responsibility	Yes	Yes	Yes	No
20.	Motor protection under extreme conditions assured by *Silco-Flex* insulation system	Yes	No	No	No

DESIGN FEATURES are evaluated for high temperature liquid metal pumps in typical installation. **(FIGURE 12)**

DESIGNERS' MODELS

The Modern Engineer's Tool

CONSULTANTS, utility engineers and manufacturers' designers find scale models of steam turbine-generator units invaluable in design meetings. The model can relay much of the same information that normally must be transmitted by detailed and complex drawings.

by **W. C. FRAZIER**
Steam Turbine Department
Allis-Chalmers Mfg. Co.

Different from usual models that are built for shows and exhibits, designers' models are actually three-dimensional layouts that design engineers live with from earliest drawing-board stages.

SCALE MODELS of steam turbines and generators are becoming increasingly useful design tools. Extremely helpful in design conferences, they have recently gained even greater importance.

The trend toward more steam-electric plants and the growing demand for power have resulted in large increases in the rated size of units for new installations. Machines that were considered to be quite large a few years ago are now rather commonplace.

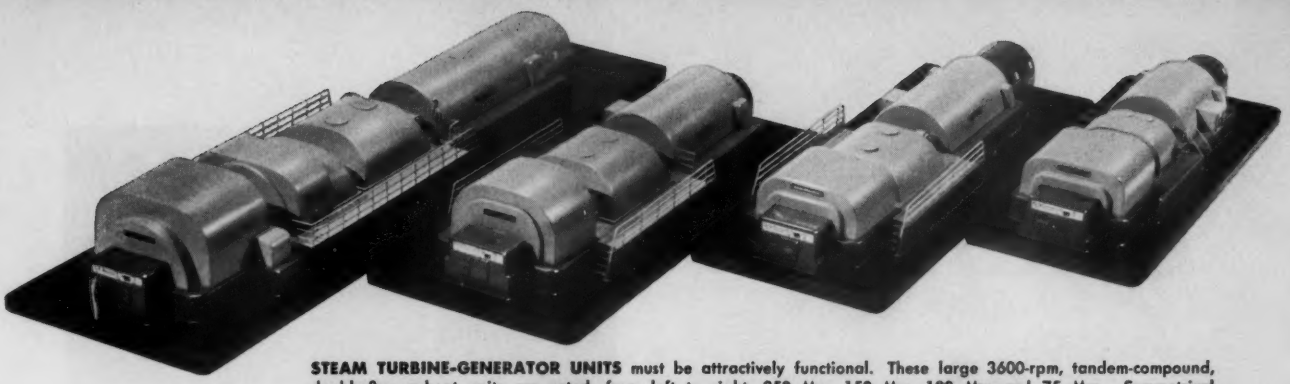
Electric utilities and manufacturers of large generating units often specify, give price estimates and predict delivery dates for machines that will not be in operation for as long as one to three years after the contract is signed. Many of the new units are precedent-setting in both rating and arrangement, making the important role of designers' models clearly evident. With the installation predicted in model form, consultants, utility engineers and manufacturer's design engineers are able to see just what the unit will look like — often decide on such details as instrument location and color of paint desired — long before the machine is produced.

The three-dimensional view enables engineers to visualize such important construction considerations as side cross-unders, and oil, hydrogen and gland-steam piping. Boundary space created by the lagging gives design engineers freedom to strategically arrange the equipment for easy accessibility and operating convenience while maintaining the modern appearance desired in present-day power plant architecture. The designers' model, made of soft wood and scaled to three-eighths inch per foot, may be revised to allow engineers to see the results of their changes in a relatively short time and at very little cost compared to the amount that would be required to make changes on completed turbine-generator units.

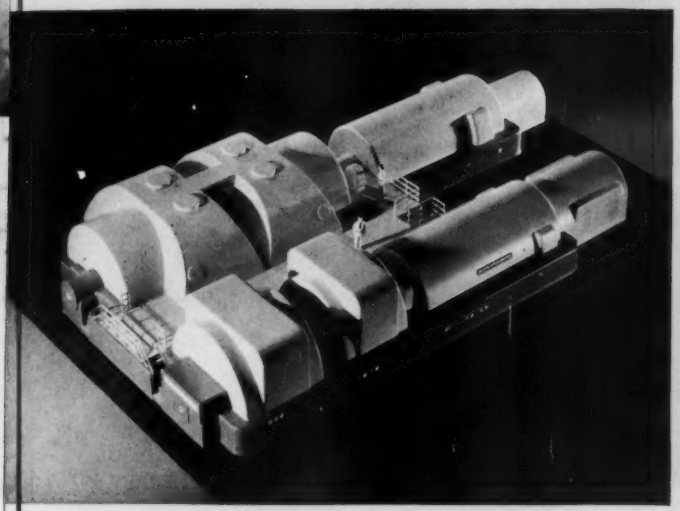
Since large steam turbine and generator design has become more complex with increases in ratings, drawings for them have necessarily become more complicated. The designers' model can relay much of the information contained on a drawing simply, quickly and comprehensively. In addition, the complex and delicate drawing can be viewed by only one or two persons at a time, while the model can be used effectively by a score of people.

Scale models of various size units help to establish a design pattern. As steam turbine generator ratings increase there is a very real attempt to build larger machines from components of smaller units. A 300-mw, cross-compound, 3600/3600-rpm unit, for example, would be similar in appearance to a pair of 150-mw, double-flow, tandem-compound 3600-rpm units. The manufacturer is thus able to project his designs into the future, and although necessary changes are made to include the latest in design, it is possible to know the approximate appearance of an entirely new design long before it is completely engineered. In an attempt to standardize on design and to develop a functional yet symmetrically similar unit, designers tend to follow the pattern of previous unit designs, thereby establishing a family resemblance. Thus the location of instrumentation, piping and various accessories is more or less duplicated on units regardless of size.

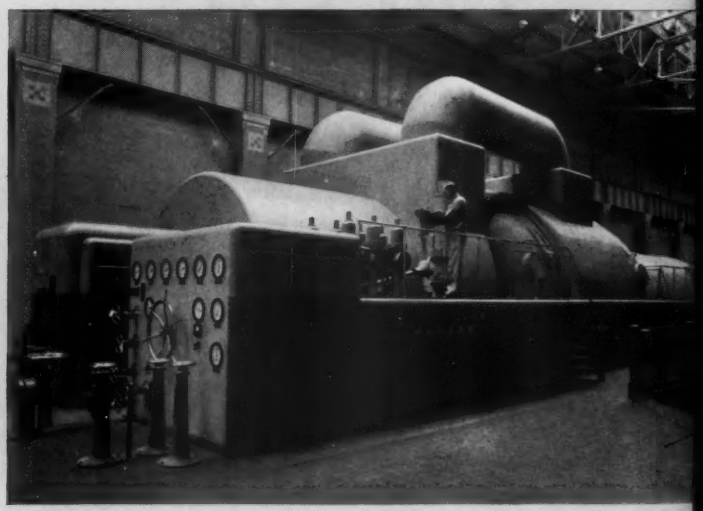
Already widely utilized throughout the power industry, new applications for scale models are being discovered as personnel become accustomed to this modern engineering tool.



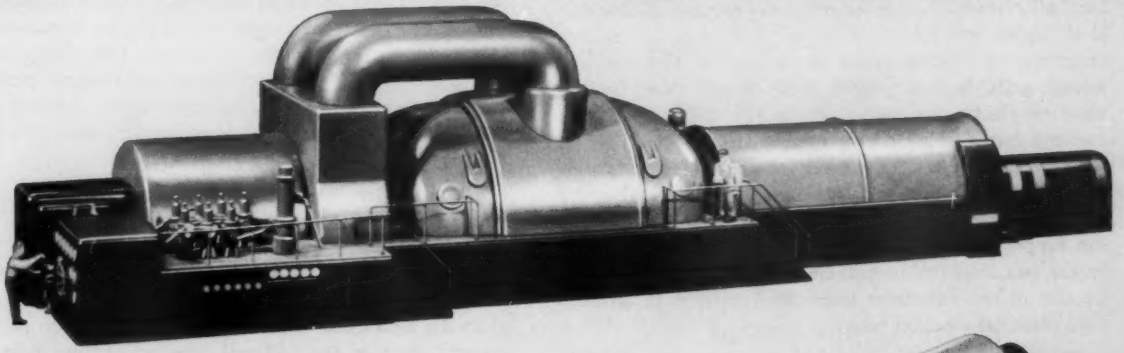
STEAM TURBINE-GENERATOR UNITS must be attractively functional. These large 3600-rpm, tandem-compound, double-flow reheat units are rated, from left to right, 250 Mw, 150 Mw, 100 Mw and 75 Mw. Symmetrical design is easily appreciated in the scale models. The boundary space created beneath the lagging and apron permits the designer to conceal the crossunder piping and locate the instruments for maximum accessibility.



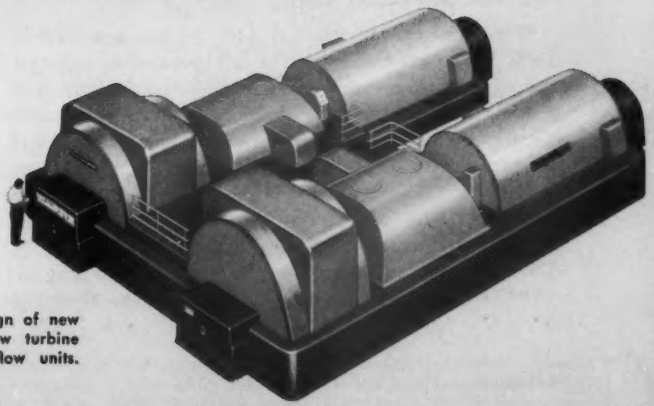
MORE THAN 85 PERCENT of the total generating capacity ordered for delivery through 1963 will be steam turbine-generator units. Since it takes several years to design and produce a machine, such as the 321-Mw unit shown in model form, it is desirable that the design engineers be able to view a new design at an early date.



CLOSE SIMILARITY of an actual unit to its model, shown below, is testimony to the model's effectiveness. The unit shown is one of five 80,000-kw, 1800-rpm, reheat tandem-compound double-flow machines operating at the Port Washington station of the Wisconsin Electric Power Company. Note how the fine detailing compares to the model.



A MAJOR APPLICATION of steam turbine-generator models is an aid to appearance design. Built precisely to scale, the models enable turbine and generator design engineers to visualize the finished product months, often years, before a unit is installed. This approach has led to alterations in apron and lagging design as well as relocation of instruments and controls for maximum accessibility and pleasing appearance.



MODELS ALLOW ENGINEERS to predict the future design of new and larger units. This 300-Mw, 3600/3600-rpm, four-flow turbine model resembles a pair of 150-Mw, 3600-rpm, double-flow units.

NEW LIGHT on FUEL CELLS

by **J. P. MANION**
Research Laboratories
Allis-Chalmers Mfg. Co.

EXPERIMENTAL FUEL CELL, operating on chemical reaction of gases, is being studied as new hope for dc power source.

Fuel cell may provide new source of electric energy for industrial loads.

RESEARCH SCIENTISTS AND ENGINEERS in a number of large companies are now looking to the fuel cell as a more efficient method of converting chemical energy to electric energy.

As a device which provides direct current power, the fuel cell resembles other electric cells but has a considerably higher efficiency. Like all batteries, it consists essentially of electrodes and an electrolyte. Conventional storage cells, however, have their energy stored in the electrode-electrolyte system within the cell, whereas the fuel cell can store no energy within the cell itself. It instantaneously converts chemical energy to electric energy. A fuel, such as hydrogen, supplied from an external source can furnish this chemical energy. In theory, a fuel cell can supply electric power as long as the fuel supply lasts. In the past, fuel cell performance left much to be desired because of the difficulties associated chiefly with unfavorable chemical reaction rates.

What was probably the first fuel cell was described by Sir William Grove in 1839. The cell operated on hydrogen and oxygen.[1] Fifty years later, in 1889, particularly good results were reported by Ludwig Mond and Charles Langer,[2] who obtained a relatively high current density of six amperes per square foot with essentially the same type cell. In 1921, Professor E. K. Rideal[3] discussed "The Problem of the Fuel Cell" before The Faraday Society. A few of the more recent fuel cell investigators include O. K. Davtyan[4,5] in Russia (1946), F. T. Bacon[6] in England (1935 to the present) as well as scientists of the Pittsburgh Consolidated Coal and Coke Company, National Carbon Company and others in the United States. Several types of fuel cells are being investigated. Among these are direct fuel cells utilizing solid fuel, semidirect cells which utilize gaseous fuel, and indirect cells utilizing an oxidation-reduction (redox) system.

Engineers see in the fuel cell a valuable energy conversion method through use of off-peak generator facilities to produce hydrogen and oxygen which can be stored, transported and utilized at will in fuel cells. Low voltage constant loads of such electrochemical processes as plating, water purification, galvanizing, electrolytic cleaning and electrolytic refining of metals could make use of this type of energy.

When the free energy of the reaction is converted directly into electric energy, as is the case in the fuel cell, there is no theoretical limitation on efficiency. The possibility of producing electric power directly from a fuel at an efficiency of 90 percent is truly startling when compared to the best diesel engines, which are about 40 percent efficient. Because the fuel cell does not involve heat but converts chemical energy directly into electric energy, it escapes the high heat engine energy losses.

In the cell shown in Figure 1, hydrogen gas is adsorbed onto the catalyst at the anode electrode and is activated there, causing it to react with an ion in the electrolyte to form water. This reaction releases an electron to the external circuit. At the cathode electrode oxygen gas is adsorbed and activated, causing it to react with an electron from the external circuit and with the electrolyte to reform the ion which disappeared at the anode. The overall

reaction is the disappearance of hydrogen and oxygen to yield water and produce a flow of electrons via the external circuit at the voltage characteristic of the chemical reaction. The electrons that flow through the load are forced to do so before the chemical reaction is completed. Consequently, all the electric energy delivered by the cell is converted chemical energy.

Research work on the fuel cell has included a study of a cell operating at elevated temperatures and a preliminary survey of the redox cell as well as the cell shown, which operates at room temperatures and utilizes a catalytic electrode surface. The 24-volt cell shown is one in a series of experimental laboratory models which are being constructed to incorporate research results into operating units for testing purposes.

While the fuel cells developed to date have unsolved problems, such as a significant voltage droop caused by polarization with large currents, they have features that make them attractive. They are efficient, can operate indefinitely without maintenance, and are not affected by wide temperature ranges.

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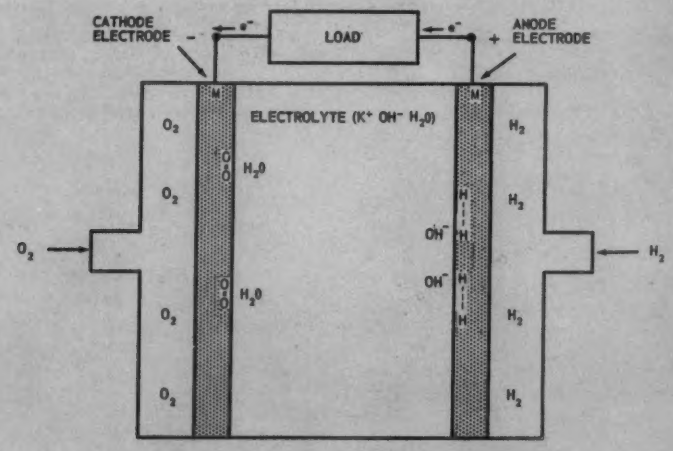


LOAD is energized by the flow of electrons, e^-, released by the reaction of hydrogen and oxygen. **(FIGURE 1)**

EQUATIONS ILLUSTRATING THE CHEMISTRY INVOLVED IN THE FUEL CELL REACTION

Cathode Reactions

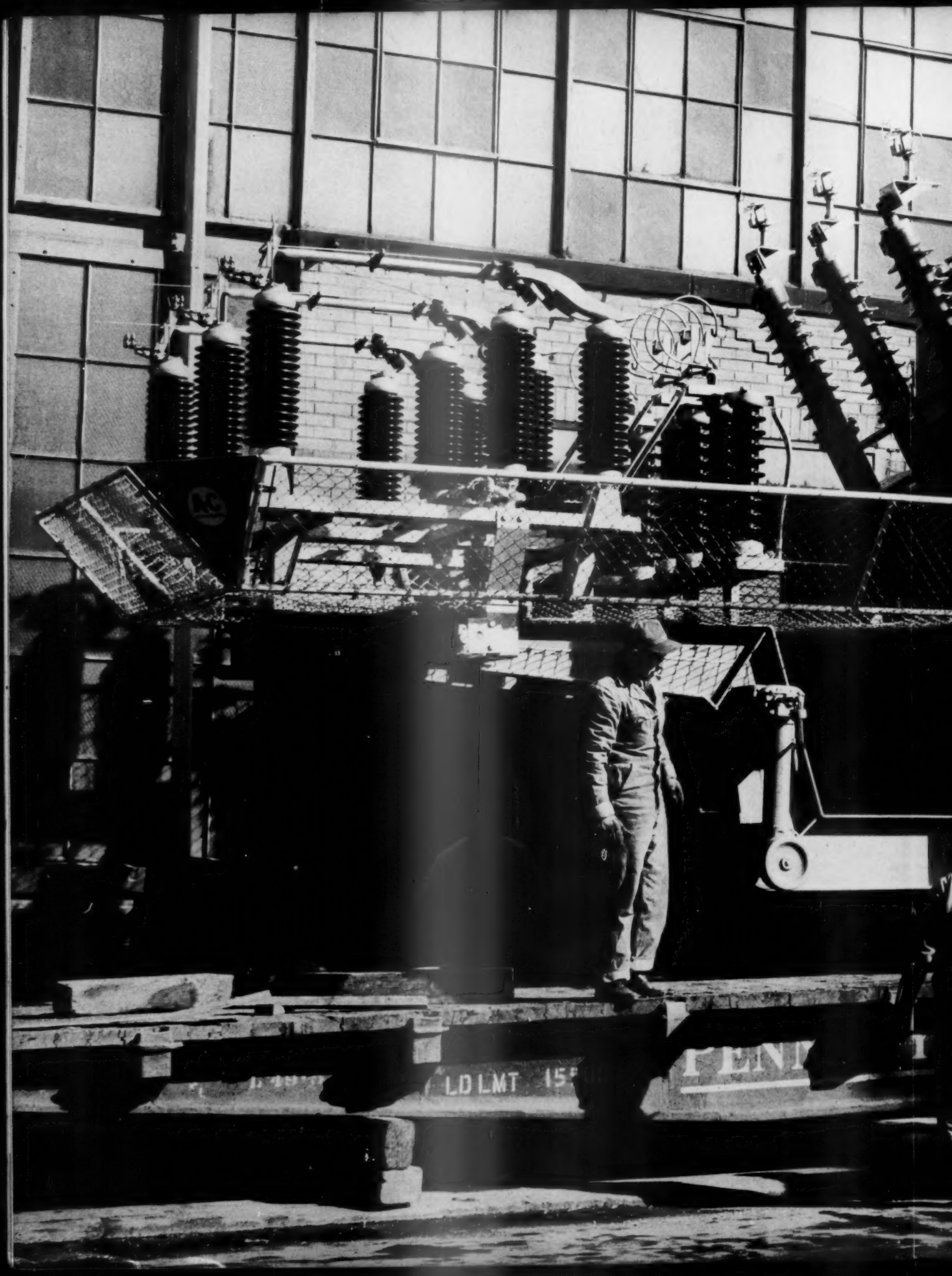
1. $O_2+M=MO_2$
2. $MO_2+e^-=MO_2^-$
3. $MO_2^-+H_2O=MO_2H+OH^-$
4. $MO_2H+e^-=MO_2H^-$
5. $MO_2H^-+H_2O=MO_2H_2+OH^-$
6. $MO_2H_2+2e^-=M+2OH^-$

Anode Reactions

1. $H_2+M=MH_2$
2. $MH_2+OH^-=MH+H_2O^-$
3. $H_2O^-=H_2O+e^-$
4. $MH+OH^-=M+H_2O^-$
5. $H_2O^-=H_2O+e^-$

M is metal electrode surface impregnated with catalyst.

MOBILE SUBSTATION GOES PIGGYBACK from Pittsburgh to Midwest utility. The substation with disconnects, protective devices, metering equipment, breaker and 7500-kva transformer is designed for either 69 or 34.5-kv primary voltages and can supply 2400, 4160, 7200 or 12,500-volt distribution systems. Three 10,000-kva mobile substations of similar design, now being built for another utility, will also be used as part of planned maintenance programs or during emergencies.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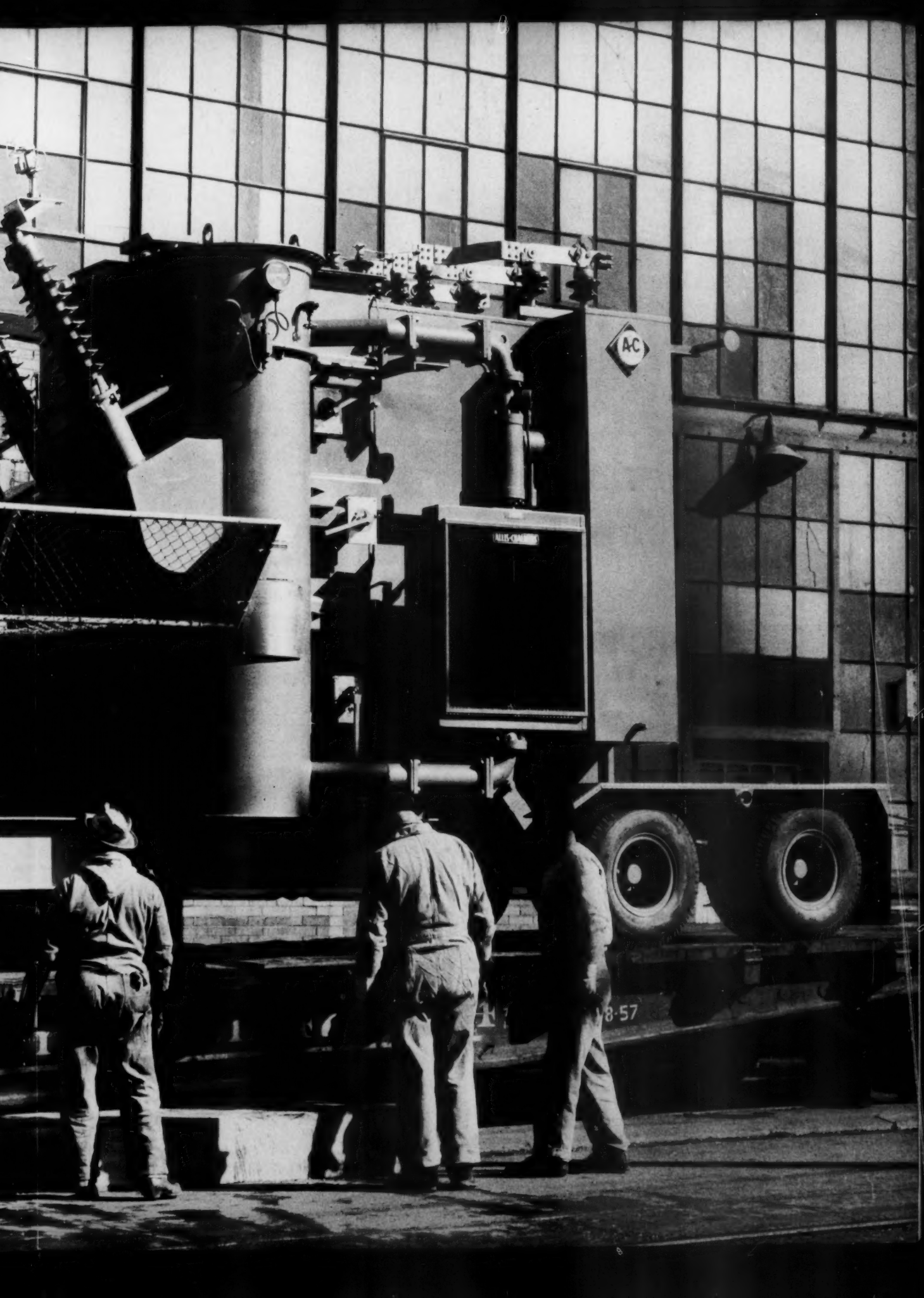

A-C
ALLIS-CHALMERS

Applying CORRELATION ANALYSIS to engineering problems

CORRELATION ANALYSIS is applied to wide variety of design problems. Performance on test of high production current transformers proves value of method.

Correlation analysis can aid the engineer in solving many of his day-to-day problems.

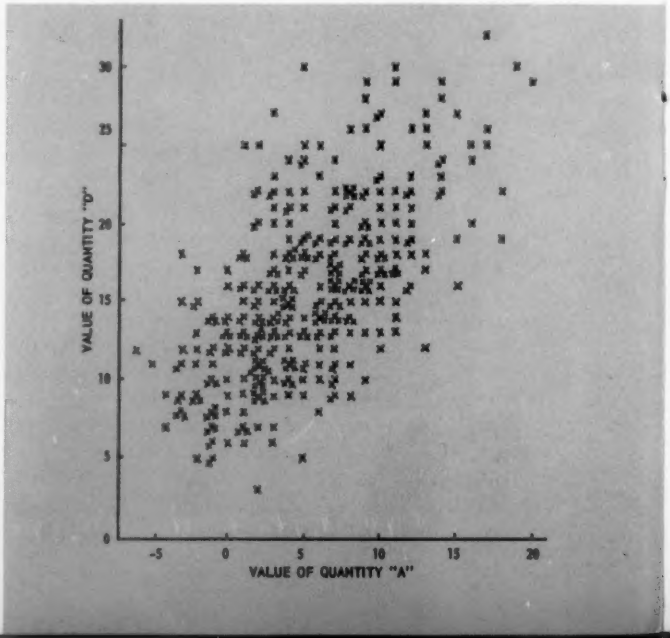
by **GEORGE SHOMBERT**
Pittsburgh Works
Allis-Chalmers Mfg. Co.

CURVE PLOTTING is an extremely useful method of obtaining, presenting and analyzing data. However, all factors except the two being studied must be held constant, and there are times when this simply cannot be done, as in the example of Figure 1. Correlation analysis is applicable to such situations. The technique, while by no means new, is not as widely used by engineers as it might be.

Applying two-variable correlation

Consider the problem of Figure 1. Quantity *A* is the value of a preliminary test on a material, sampled at an intermediate step in its processing. Quantity *D* is the value of a final test obtained on a sample taken after all processing has been completed. Each pair of *A* and *D* values is plotted as an *X* on Figure 1, which is called a "scatter chart." Now obviously there is a relationship between the *A*-value and the *D*-value, for small values of *A* tend to be associated with small values of *D*, while large values of *A* are associated with the larger values of *D*. However, there is not a one-to-one correspondence between the two, because variations in the subsequent processing after the *A* sample is taken influence the value obtained on the *D* sample. For example, a batch having an *A*-value test of 10 may run from 12 to 27 on the final test.

The problem, then, is to delineate this relationship between *A* and *D* in a simple form, susceptible to analysis and interpretation. Correlation analysis does this by cal-



CHOICE OF CURVE and its location are often impossible to guess when points are widely scattered. **(FIGURE 1)**

culating the equation of the most probable line, called the line of regression. The underlying assumption is that the most probable line is the one which will minimize the sum of the squares of the deviations. These deviations are the vertical distances from each point to the line, as shown in Figure 2. The procedure involves only simple arithmetic, although of course algebra and calculus are used to establish its validity.

It is necessary to calculate, for each point, the values of A, A^2, D, D^2 and $A \times D$, and then to obtain the sums of these values for all the points involved. This portion of the work is conveniently done on a computer, or a desk-calculator provided with automatic multiplication. For small amounts, manual computation is greatly speeded by a tabular arrangement of the work[1-6] and will usually be faster than mechanical methods of calculation.

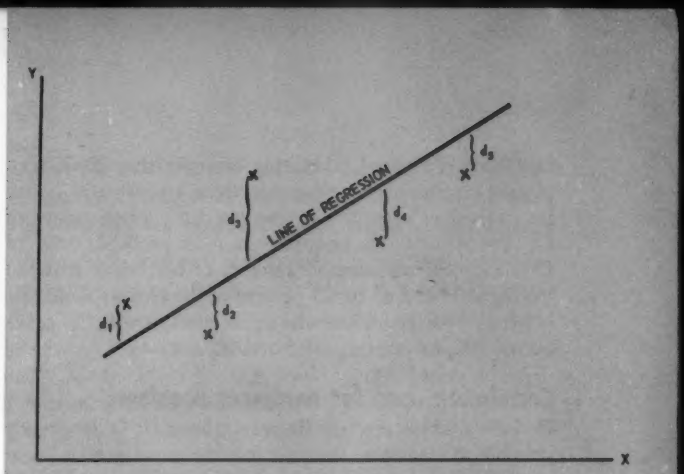
The five sums obtained are used to calculate the following:

(1) The Correlation Coefficient, r. This is a quantity between $+1$ and -1 which expresses the degree to which the points tend to cluster about the line of regression. If every point fell exactly on the line, the correlation coefficient would be either $+1$ for a line sloping upward to the right, or -1 for a line sloping downward to the right. If there were no relationship between the two variables being examined, there would be no most probable line, and the value of the correlation coefficient would be zero. For the data of Figure 1, the correlation coefficient is found to be $+0.63$.

The calculations which resulted in this value could have been performed on any set of number-pairs, even if they were totally unrelated. To determine whether the value of 0.63 indicates a genuine relationship between A and D, refer to Table I, second column, and interpolate between $n = 300$ and $n = 400$, since there are 367 points on the scatter chart. The critical values are found to be 0.103 (5 percent) and 0.135 (1 percent). The meaning of these numbers is: (a) On 367 pairs of values, there is only one chance in 20 that a correlation coefficient as high as 0.103 will be obtained by chance. Put the other way, if the correlation coefficient exceeds 0.103, there is a 95 percent probability that the variables are truly related. (b) There is only one chance in 100 that a value as high as 0.135 will be obtained by chance.

Since 0.63 is far above 0.135, there is virtual certainty that variables A and D are related. Incidentally, note that a correlation coefficient much below the 5 percent critical value would indicate a lack of relationship.

(2) The square of the correlation coefficient also has meaning. The value of D, in the example we are using, shows considerable variation, ranging from $+3$ to $+32$. Some of this is explainable by variations existing at the time the sample A is taken, while some is due to variations introduced in later processing, plus a residue of variation due to sampling and testing errors. The portion of the variation in D which is explained by the variation in A is equal to the square of the correlation coefficient — in this case $(0.63)^2$ or approximately 40 percent.



MOST PROBABLE LINE, line of regression, is the line for which $d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2$ is minimum. **(FIGURE 2)**

(3) The equation of the line of regression can be calculated, and if desired the line itself can be plotted on the scatter chart, as is done in Figure 3.

(4) Confidence limits are sometimes useful and can be

TABLE I

Degrees of Freedom	Number of Variables				Degrees of Freedom	Number of Variables			
	2	3	4	5		2	3	4	5
1	.997 1.000	.999 1.000	.999 1.000	.999 1.000	24	.388 .496	.470 .565	.523 .609	.562 .642
2	.950 .990	.975 .995	.983 .997	.987 .998	25	.381 .487	.462 .555	.514 .600	.553 .633
3	.878 .959	.930 .976	.950 .983	.961 .987	26	.374 .478	.454 .546	.506 .590	.545 .624
4	.811 .917	.881 .949	.912 .962	.930 .970	27	.367 .470	.446 .538	.498 .582	.536 .615
5	.754 .874	.836 .917	.874 .937	.898 .949	28	.361 .463	.439 .530	.490 .573	.529 .606
6	.707 .834	.795 .886	.839 .911	.867 .927	29	.355 .456	.432 .522	.482 .565	.521 .598
7	.666 .798	.758 .855	.807 .885	.838 .904	30	.349 .449	.426 .514	.476 .558	.514 .591
8	.632 .765	.726 .827	.777 .860	.811 .882	35	.325 .418	.397 .481	.445 .523	.482 .556
9	.602 .735	.697 .800	.750 .836	.786 .861	40	.304 .393	.373 .454	.419 .494	.455 .526
10	.576 .708	.671 .776	.726 .814	.763 .840	45	.288 .372	.353 .430	.397 .470	.432 .501
11	.553 .684	.648 .753	.703 .793	.741 .821	50	.273 .354	.336 .410	.379 .449	.412 .479
12	.532 .661	.627 .732	.683 .773	.722 .802	60	.250 .325	.308 .377	.348 .414	.380 .442
13	.514 .641	.608 .712	.664 .755	.703 .785	70	.232 .302	.286 .351	.324 .386	.354 .413
14	.497 .623	.590 .694	.646 .737	.686 .768	80	.217 .283	.269 .330	.304 .362	.332 .389
15	.482 .606	.574 .677	.630 .721	.670 .752	90	.205 .267	.254 .312	.288 .343	.315 .368
16	.468 .590	.559 .662	.615 .706	.655 .738	100	.195 .254	.241 .297	.274 .327	.300 .351
17	.456 .575	.545 .647	.601 .691	.641 .724	125	.174 .228	.216 .266	.246 .294	.269 .316
18	.444 .561	.532 .633	.587 .678	.628 .710	150	.159 .208	.198 .244	.225 .270	.247 .290
19	.433 .549	.520 .620	.575 .665	.615 .698	200	.138 .181	.172 .212	.196 .234	.215 .253
20	.423 .537	.509 .608	.563 .652	.604 .685	300	.113 .148	.141 .174	.160 .192	.176 .208
21	.413 .526	.498 .596	.552 .641	.592 .674	400	.098 .128	.122 .151	.139 .167	.153 .180
22	.404 .515	.488 .585	.542 .630	.582 .663	500	.088 .115	.109 .135	.124 .150	.137 .162
23	.396 .505	.479 .574	.532 .619	.572 .652	1000	.062 .081	.077 .096	.088 .106	.097 .115

Table of Critical Values for Correlation Coefficient[5]
Light Face Type — 5%
Bold Face Type — 1%

calculated if desired. For this example they have been plotted on Figure 3. Note that there are two sets — one for individual values of D, and one for average values of D. For $A = 10$, for example, the most probable value of D is 19.3. If we sample a number of batches of material having an A-test of 10, 95 percent of the D-tests should lie between 10.8 and 27.8, while the average will, 95 times out of 100, lie between 18.6 and 20.0.

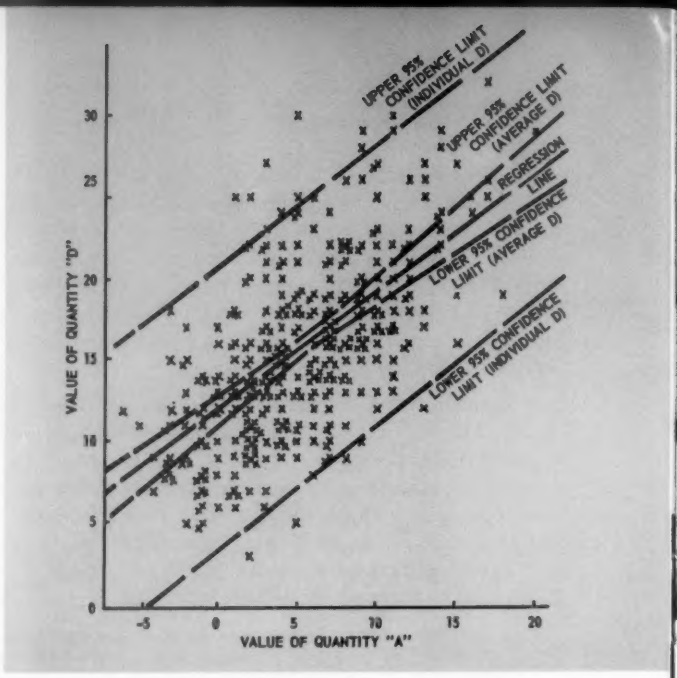
Correlation used for nonlinear problems

If the variables are not linearly related, it is frequently possible to transform them so that the technique of linear correlation may be applied. Figure 4 is an example of such a problem. Interfacial tension (IFT) and resin number* are two of many tests which can be applied to transformer oil; both tests were made on 500 samples of oil. A scatter chart on linear graph paper shows that a nonlinear relationship exists between the two, but on logarithmic paper the relationship becomes linear, at least within the limits indicated. The correlation calculations were therefore performed on the logarithms of the variables. The correlation coefficient was found to be —0.644, and the equation of the line of regression is:

$$(\text{IFT})\ (\text{Resin No.})^{0.214} = 18.6$$

Having found that a correlation exists between interfacial tension and resin number, how is that fact applied? One obvious step would be to discontinue making the resin number test, for its value can be predicted from the equation after the IFT is measured. However, before making this decision, one should examine the mavericks — the points which lie outside the 95 percent confidence limits. Transformer oil is not a simple substance, and it might well be that in these cases the resin number test is giving important information which is not revealed by the interfacial tension test. If this is found to be so, one might decide to continue making both tests, accepting 19 unnecessary tests as a fair price for one which is extremely useful.

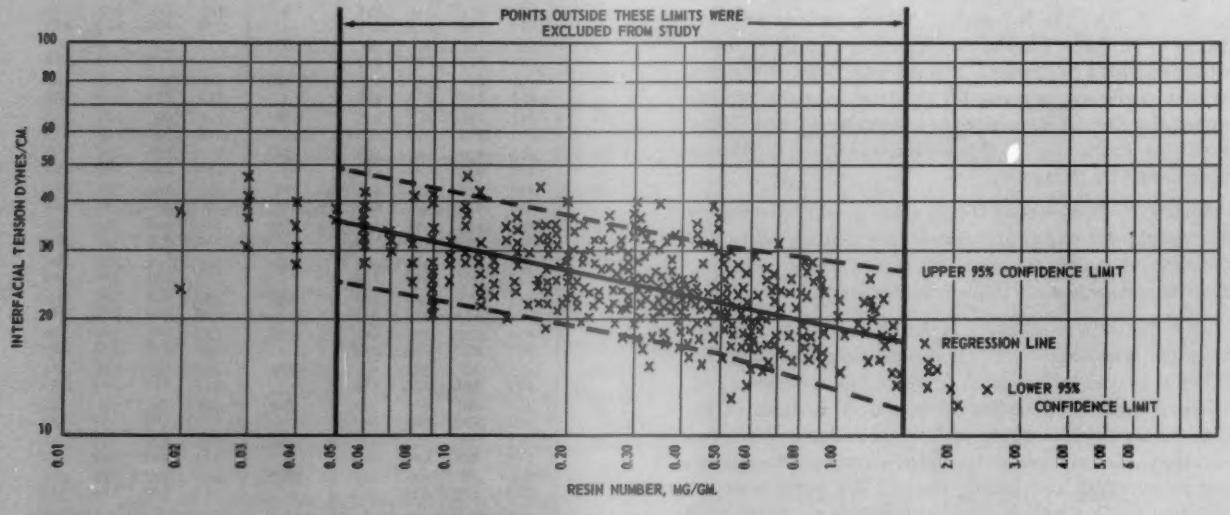
* Resin number is the term applied to the difference between total acidity of an oil as measured by saponification number and the free acid content measured by ASTM neutralization number.



UPPER AND LOWER confidence limits and regression line are plotted for the scatter points of Figure 1. **(FIGURE 3)**

Method extended to several variables

In discussing the example of Figure 1, it was pointed out that only 40 percent of the variation in D is due to variation in the A-sample. It follows, then, that the remaining 60 percent is due to subsequent processing, and examination of the process parameters by the correlation technique should therefore be rewarding. Two such parameters are



LINEAR CORRELATION techniques can frequently be applied to nonlinear problems simply by using logarithmic paper. **(FIGURE 4)**

H and S; these values were recorded for the 367 batches studied. These data are not reproduced here; scatter charts for D vs. H and D vs. S were plotted and are similar in appearance to Figure 1. The correlation coefficient between D and H, written r_{DH}, is below the 5 percent critical value and is therefore probably not significant, while r_{DS} is above the 1 percent critical value and is therefore almost certainly significant.

It happens that H and S are themselves related, both being ultimately determined by the weight of the batch. Under these circumstances the simple two-variable values r_{DH} and r_{DS} are further operated on to yield new values, $r_{DH.S}$ and $r_{DS.H}$. The value of $r_{DS.H}$ is -0.127 — not strikingly different from the value of -0.157 for r_{DS}, and still statistically significant. However, the value of $r_{DH.S}$ is only -0.016, far below the value of -0.095 obtained for r_{DH}. This confirms the previous impression that H is unimportant.

A and S are not related; no use is made of the value of the A-test at the step in the processing represented by S. Would better results be obtained if the processing at step S were adjusted to the A-value of the batch? Multiple correlation provides the answer to this important question:

$r_{DA.S} = +0.636$, whereas $r_{DA} = +0.630$

$r_{DS.A} = -0.180$, whereas $r_{DS} = -0.157$

The small differences indicate that the effect of S is independent of the A-value.

Solves engineering problems

The technique once mastered, it will be found that correlation analysis is a tool extremely useful in the solution of engineering problems. Of the many examples which might be cited, these two must suffice:

(1) Quality Control of Current Transformers:

The performance of a current transformer is measured by its ratio error*, and this may be shown to be dependent only on the core loss and exciting current of the transformer. These quantities in turn depend on the quality of the silicon steel used in the transformer core. On a number of coils of steel, the magnetic properties (watts/lb and volt-amperes/lb) were determined by Epstein tests. Sample transformers were also made from these coils and the ratio error measured. These data cannot conveniently be displayed graphically, being three-dimensional, but it can be said that processing variations and design considerations introduce scattering analogous to that shown in Figure 1. Furthermore, since the core loss and excitation requirement of the steel are themselves closely related, it is necessary to use multiple correlation procedures.

The correlation coefficient between ratio error of the transformer and core loss of the Epstein sample, $r_{XY.Z}$, was $+0.288$.

The correlation coefficient $r_{X.YZ}$ was $+0.727$, indicating that the core loss and excitation requirements of the steel together account for 53 percent ($0.727^2 = 0.53 =$ 53 percent) of the variation in the finished transformers.

From these results it was possible to set limits for the Epstein test values on the material which would insure a satisfactory transformer — given normal processing and workmanship and assuming no unusual design characteristics. Material has been selected on this basis for over three years with entirely satisfactory results.

(2) Performance of Power Transformers:

One aspect of the performance of a power transformer is measured by the variable X_5. Four factors thought to influence X_5 were designated X_1, X_2, X_3, and X_4. Data were accumulated on 90 transformers in all, and the calculations performed to yield the following values:

$$R\ (X_{5.1234}) = +0.8072$$
$$R\ (X_{15.234}) = +0.7742$$
$$R\ (X_{25.134}) = +0.1557$$
$$R\ (X_{35.124}) = +0.4378$$
$$R\ (X_{45.123}) = -0.0122$$

$R\ (X_{5.1234})$ is the total correlation between the dependent variable X_5 and the dependent variables X_1, X_2, X_3, and X_4 varying jointly. $R\ (X_{15.234})$ is the partial correlation between X_5 and X_1 with the disturbing effect of X_2, X_3, and X_4 suppressed.

Reference to Figure 3 shows that X_2 and X_4 are not significant factors. Measurement of these quantities is a waste of time and should be discontinued. The regression equation is:

$$X'_5 = 1.07X_1 + 2.17X_3 - 0.73X_2 - 0.019X_4 + 34.52$$

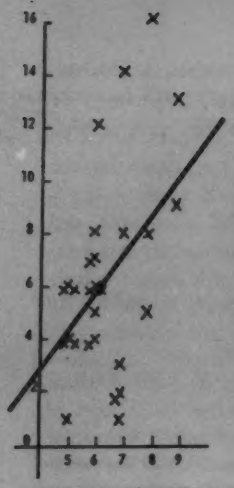
Observe the large constant term 34.52. The value of X_5 ranges from 55 to 70 units, of which the four factors presently being measured contribute 20 to 35 units and the remaining 35 units come from some factor or factors not now being measured. The next step, obviously, is to identify these factors and repeat the analysis, dropping out X_2 and X_4.

Estimating the line by eye is not safe practice

An engineer not familiar with the methods of correlation analysis might draw a line on the scatter chart, estimating its position by eye, for want of any better procedure. The hazard of this operation is dramatically shown in Figure 5. The least-squares line does not appear to fit the points very well; it would seem that the line on the right ought to be a much better fit. Yet the sum of the squares of the vertical distances from the several points to the line is only two-thirds as much for the least-squares line as it is for the line on the right.

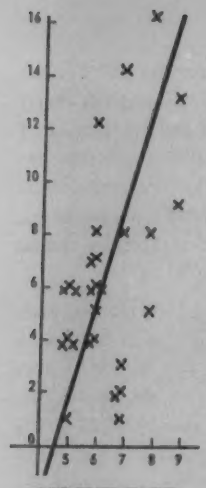
Like any other tool, correlation analysis can be misapplied. The mechanism will work on any set of numbers, whether they be obtained as a result of measurements or drawn out of a hat. Therefore, the analyst must exercise

* There is also an error in phase angle, but in this problem it was negligible.



LEAST – SQUARES LINE

$(3.5)^2 =$	12.25
$3(0.5)^2 =$	.75
$3(1.5)^2 =$	6.75
$2(1.9)^2 =$	7.22
$(0.9)^2 =$	0.81
$3(0.0)^2 =$	0.00
$2(1.1)^2 =$	2.42
$(2.1)^2 =$	4.41
$(6.1)^2 =$	37.21
$(6.2)^2 =$	38.44
$2(5.2)^2 =$	54.08
$(4.2)^2 =$	17.84
$(0.8)^2 =$	0.64
$(6.8)^2 =$	46.24
$(3.5)^2 =$	12.25
$(0.5)^2 =$	0.25
$(7.5)^2 =$	56.25
$(1.0)^2 =$	1.00
$(3.0)^2 =$	9.00
Total =	307.81



LINE DRAWN BY EYE

$(0.2)^2 =$	0.04
$3(2.8)^2 =$	23.52
$3(4.8)^2 =$	69.12
$2(1.0)^2 =$	2.00
$(0.0)^2 =$	0.00
$3(1.0)^2 =$	3.00
$2(2.0)^2 =$	8.00
$(3.0)^2 =$	9.00
$(7.0)^2 =$	49.00
$(7.5)^2 =$	56.25
$2(6.5)^2 =$	84.50
$(5.5)^2 =$	30.25
$(0.5)^2 =$	0.25
$(5.5)^2 =$	30.25
$(7.3)^2 =$	53.29
$(4.3)^2 =$	18.49
$(3.7)^2 =$	13.69
$(7.0)^2 =$	49.00
$(3.0)^2 =$	9.00
Total =	508.65

POSITIONING a curve by eye could lead to serious design errors. Possible variance in results is indicated by the difference in totals. **(FIGURE 5)**

some discretion in the interpretation of his results, as it is entirely possible to find an apparent correlation which is more correctly explained in some other way.

The classical illustration of this point is that for about 30 years prior to World War I, a strong correlation existed between teachers' salaries and consumption of liquor. The obvious conclusion is incorrect. Actually, both these quantities were closely coupled to the general prosperity level. An increase in prosperity caused both quantities to rise, while a decrease caused both to fall. Thus a spurious correlation could be demonstrated mathematically, even though it has no basis in reality.

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FACTORS determining the life of transformer oil have been under study for years. Correlation of test data will provide basis of future standards.

Is "PATENT KNOWLEDGE" One of Your Working Assets?

by **H. L. SWENSON**
Patent Attorney
Allis-Chalmers Mfg. Co.

"An investment in knowledge pays the best interest . . ."

— Benjamin Franklin

THE ENGINEERING GROUP which takes the time to become acquainted with the basic workings of our patent system will prove that Benjamin Franklin was right. When properly applied, the knowledge gained from investing a little time and effort in the study of patents and their effects is an invaluable asset. In addition to assisting in the protection of your patentable inventions, an investment in patent knowledge can also be used as an aid in avoiding costly infringement liabilities. Although a general acquaintance with patent practices will be inadequate for the purpose of handling your own patent matters, it can serve as a reminder to work closely with your patent counsel on the various patent questions which are a natural outgrowth from engineering and development work — questions which you would otherwise be unaware of.

Similar to a series of patent questions in the 1st Quarter, 1958, issue of this publication, the following additional questions have been raised by engineering personnel. Have you made a sufficient investment in "patent knowledge?" See how many of the questions you can answer correctly.

QUESTION	ANSWER
1. If a product is patented in a foreign country, do you have any protection in the United States? And conversely, if the product is patented in the United States, do you have any protection in foreign countries?	1. No, on both counts. The scope of protection afforded the patent does not extend past the territorial limits of the country granting the patent.
2. If you obtain a patent in a foreign country does this automatically entitle you to a patent on the invention in the United States?	2. No. The standard of invention of patent offices in different countries varies.
3. What should a person first do when he gets an idea that may be patentable?	3. The person should first describe on paper means for effectuating his idea and have it signed and dated by two others who understand the operation of the idea. This is generally called a disclosure and its purpose is to provide a witness who is able to corroborate the testimony in regard to a date of existence of the means for effectuating the idea in the event of a future dispute as to who is first inventor.
4. What is infringement?	4. It is an unauthorized manufacture, sale or use of that which is patented and which occurs within the territorial limits of the country granting the patent and during the life of the patent.
5. The following paragraph appears at the end of the specification of a patent and is referred to as a: (a) right? (b) claim? (c) allegation? (d) description? A battery plate separator comprising fibrous glass sheets adhered together by an interposed layer of fine short glass fibers each coated with an adhesive thermoplastic synthetic resinous material.	5. (b) Claim. This may be considered to be the fence or profile of the invention as it defines the invention. Whether or not an infringement exists will depend upon what is covered by the claim.

QUESTION	ANSWER
6. Must all claims of the patent be infringed before infringement can be asserted?	6. No. Only one claim need be infringed.
7. Is an unauthorized making of a patented article, just for your own use, an infringement?	7. Yes. The unauthorized making of a patented article is an infringement regardless of the extent of its use.
8. Does a U.S. patent prevent our government from using the patented invention?	8. No. A patent owner cannot stop the use by or for the government but may sue in the Court of Claims for a reasonable compensation.
9. The following hypothetical claim covers the illustrated chair: True or false? A chair comprising a seat, a supporting back and three legs mounted to said seat. 	9. True. The claim, although describing a chair having three legs, is not limited to chairs having no more than three legs. The illustrated chair has all of the elements of the claim and is thereby covered by it.
10. Once a person obtains a patent on his invention he need no longer be concerned about infringing any other patent when he makes his patented invention. True or false?	10. False. There is the possibility of an earlier granted patent which has claims reading on the later patented invention. This is particularly true when the later issued patent is an improvement patent. For example, assume a patent has a claim covering a chair having three legs. A later improvement patent issues on a chair having four legs. As indicated in question 9, the claim of the first patent covers the second patented invention. This type of situation occurs because the U.S. Patent Office is concerned with whether there is patentable invention and not whether the invention infringes an earlier patent.
11. What is cross licensing?	11. Cross licensing is the exchanging of patent licenses permitting the parties to make, use or sell each other's patented invention. Cross licensing is often done in the type of situation outlined in question 10, where neither party can lawfully make the improved chair without obtaining the consent of the other party.
12. What recourse does a patentee have against an infringer?	12. He may obtain an injunction or recover money damages not less than a reasonable royalty. Occasionally treble damages are awarded for willful infringement.
13. Is it really worthwhile to go to all of the bother and expense involved in obtaining a patent?	13. This should be an ever present question and the answer should be correlated to the commercial potential of the invention and the expected available patent protection. If the invention is commercially unsound or would receive only narrow claims which could be easily designed around, perhaps patent protection should not be sought.

ENGINEER PRESENTS his "Completed Work" project, including proposal, project data and other related material, to his manager without discussion. Information is complete enough to give manager the necessary pertinent information. **(FIG. 1)**

GOOD MANAGEMENT with "Completed Work"

by **G. E. FELDMAN**
Wage Administration and
Research Section
Allis-Chalmers Mfg. Co.

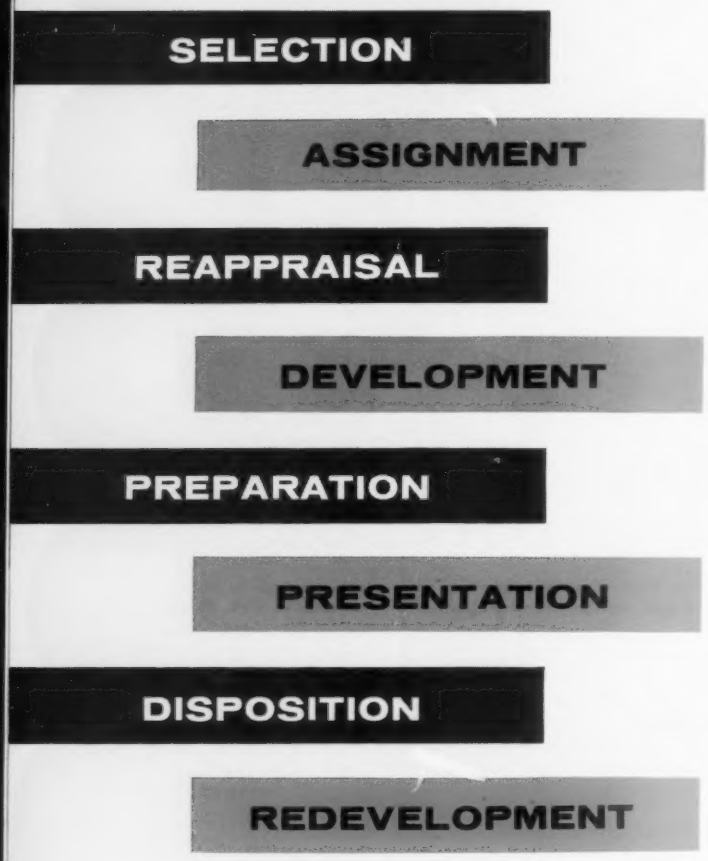
When engineers develop finished projects on their own initiative, they and their manager work together most efficiently.

A POPULAR CONCEPTION is that the engineer is a quiet, studious fellow who works in a peculiar environment of formulas and speaks in a language so filled with the special words and phrases of engineering as to be completely unintelligible to the average man. Thousands of graduate engineers in supervisory, managerial and executive roles smile when they are reminded of this concept. For these men, slide rules, formulas, and technical talk are only part of their work. Much of their engineering work is usually performed by others, but it is their responsibility to properly train, lead, guide and coordinate engineers, scientists, technicians and office personnel so that they may do their work economically and well.

Graduate engineers as a group have many qualifications which make them good management material. Typically they are, and have been trained to be, analytical, painstaking, logical and systematic. They might also be expected to have a good questioning attitude as well as a devotion to factual data as opposed to unsubstantiated opinion. Generally, there is one facet of the graduate engineer which is permitted to go undeveloped — his skill in leading others.

The well-trained engineer knows how to do a job — knows how to solve a problem — how to evaluate alternatives. Certainly the engineer who becomes a manager is likely to be an individual who has confidence in his ability to do these things well. On the other hand, the engineer-manager unskilled in leading others finds it much easier to solve the problems and make the determinations himself rather than delegate the responsibility to others.

The engineer in the supervisory, managerial or executive role can easily slip into a position where he has a strong hand in the development of every project produced by his department. He decides how to tackle a problem — he suggests what the possible solutions might be — he selects the best alternative — he proposes the tests which will prove the design. He may even find that it is he who decides whether the graph should be red or green. His staff learns that each project will become, in reality, their manager's own handiwork. He is, however, not really a manager. Instead, he is a super-engineer, relieved of some of engineering's detail work, but still making every major and minor decision in his department. There are four skills which the manager-engineer must learn if he is to escape the trap. These skills are: delegation of authority; proper assignment of work; selective checking of work quality; evaluation of individual abilities. These skills are not easy to learn and are harder still to apply. But until the manager can utilize these skills, he is not truly a manager.



Good management fosters initiative

The first step in managing skilled people is to loosen rather than tighten the reins of control. The manager must guide his staff in a general way without permitting himself to over-guide. Passing on not only the routine work but also the idea processes to his staff frees their imaginations for more creative thought. The engineers, in turn, must learn to give up over-dependence on their managers. It is a frightening experience to see full-grown men, experts in their own right, standing as a body around a manager or supervisor waiting for him to make one or more minor decisions. Managers must avoid their own natural tendency to over-guide and must discourage their engineers from asking for over-guidance.

A good technique is to turn the question back to the questioner. For example, when an engineer asks his supervisor what material should be specified for a given part, the supervisor returns the problem by asking "What do you recommend and what are your reasons?"

Another problem which most managers encounter, and which over-guidance encourages, is the "idea" problem. It can begin with the phrase, "I have an idea how we can . . . " and invariably, if it sounds valuable, the manager or supervisor could devote a considerable amount of time to gathering information so as to properly evaluate the idea. The manager who cannot protect himself from his subordinates' impulsive ideas might find himself examining and evaluating the good, indifferent, and poor proposals with equal attention.

For example, a manager might be faced with the idea "I'll bet we could save money if we buy this as a purchased part." After devoting considerable time and thought to investigating the idea personally, he might be surprised to discover that anticipated sales of the product involved were negligible. The "idea" man had started the manager on a routine investigation which he himself was too lazy or too impulsive to consider.

The answer to good management is good work by subordinates. The staff must learn to think through problems — to examine their own ideas and proposals, and to make complete recommendations and mature decisions. A capable staff exercising independent thought on major projects needs only careful coordination to be many times more useful than an equally capable staff which tries to echo and anticipate its leader in carrying out routine assignments hinging on his minor decisions.

Completed Work is a policy of leadership which can be very valuable to any manager who finds himself so involved in his subordinates' work that he has neither the time to manage nor the time to learn to manage. Many managers and supervisors have been applying Completed Work without ever identifying it as such. The manager or supervisor who for the first time adopts Completed Work will discover the results can be a major improvement in work accomplishment and in staff development.

Completed Work is a simple approach

Completed Work means work which is developed so thoroughly by subordinates that the manager can, in reviewing a single package, determine the nature of the project, all the factors which bear on the assignment, the alternatives worthy of consideration, the recommendation of the subordinate, and the reasons for proposed action. When a project or proposal has been properly prepared, it should include everything necessary so that the manager can make a reasonable decision about the subject.

The eight steps to successful Completed Work are:

1. *Selection* — Manager selects engineer to do the job.
2. *Assignment* — Manager presents the project to the selected engineer.
3. *Reappraisal* — Manager, engineer reappraise project.
4. *Development* — Engineer develops the project.
5. *Preparation* — Engineer prepares final proposal.
6. *Presentation* — Engineer presents project.
7. *Disposition* — Manager accepts project or returns it.
8. *Redevelopment* — Engineer modifies project.

Selection is the manager's greatest responsibility

When a project is to be developed, the manager must select an individual or a team of individuals to make the required studies and to prepare the project proposal or report. This selection is the most important factor affecting the quality of the work and the time it will require for completion. To make the proper selection, the manager must know what the requirements of the project are likely

to be and the ability of each member of his staff as well as recognize in each individual special talents and interests which may bear on work performance. Sizing up the project should be a relatively simple matter for the manager. Evaluating the characteristics of each staff member is far from easy, but it is a basic management responsibility.

In selecting a subordinate for a project, there are a number of factors to consider.

1. *Current Work Assignments* — try to pick an individual who is working on a project which will soon be completed or one which can easily be transferred.

2. *Capabilities* — select an engineer who has the ability to accomplish the project assigned. It is good practice to occasionally give individuals assignments which are likely to be slightly more difficult than any project they have ever accomplished successfully in the past. However, an assignment should not be made to an individual who cannot carry it out successfully. If an individual must, of necessity, be assigned to a project which is too difficult for him, it would be advisable to divide the project into two or more separate units. Then the manager gets completed work after each unit and can maintain control, yet he is still assigning and looking for limited but complete development. Only the scope of the assignment need be modified. A project which to his most capable engineer is one project, may be two projects to a less capable individual and even more to the least capable.

3. *Interests and Talents* — match interests and talents to project assignments. Aside from natural capabilities, many individuals have special interests and talents which govern their work enthusiasm. The man who has an exceptional mathematical talent and interest would be a prime candidate for a project in which the mathematics will be demanding. The man with a social bent might receive consideration for a job which requires considerable contact with people outside his own department.

Presentation requires good two-way communications

After the project team or individual engineer has been selected, the manager makes the assignment. At that time, it is essential that he make available everything that he knows about the nature, scope, purpose and implications of the project. If he has already determined certain facts related to the project, it is his responsibility to convey them. Each project has limitations of one kind or another. These guidelines must be laid out by the manager so that his engineers will know how much time to take, what policies must be followed and what authority is to be granted.

The burden for presentation of an assignment is not on the manager alone. The engineer must learn to listen carefully and to question pointedly until he really understands what is required. Before the meeting ends, he must be confident that he knows what is expected, and the manager must be equally sure that the assignment is understood.

Reappraisal is sometimes advisable

After a project has been assigned, there may be a need for one more meeting between manager and staff member. For example, a project might be assigned with the definite understanding that the first objective would be to determine if it were feasible to undertake the project at all. In some instances, a manager might first ask an engineer to propose an approach. It should be emphasized that reappraisal takes place before the project proper is begun.

It is so easy to ask the manager. His experience and knowledge qualify him to answer many questions well. His advice is invaluable. And yet, asking the manager can prove to be a dangerous crutch, because an engineer will not learn to gather information himself. In Completed Work he learns about sources of information. He reads to gain background on his subject; contacts people of his own level in the department; makes contact with other departments, and sometimes goes outside the company for information. Then he develops his own data and evaluates a situation. Selecting the worthwhile alternatives or the useful ideas, he draws his own conclusions and makes his own proposal.

Preparation must be thorough

Good development — clear thinking, reliable data and sound conclusions are not used to the fullest without thorough preparation. The engineer must write his project, proposal or recommendation in a concise yet complete form. It must be so complete that the manager can find in the report the answers to his questions about data sources, accuracy of statements and reasons for conclusions. Unusual wording, complex sentence structure and words which are not in general usage can only cloud the principal facts and reasons.

Sometimes an individual must use data which is estimated or which lacks reliability. It is his responsibility to warn his manager in the report of the questionable accuracy of certain statements. When unusual data are used, a technical supplement should be attached to report.

For example, the engineer who recommends that a particular pump be used beyond its normal capacity in an ap-

MANAGER RECEIVING COMPLETED WORK can review it carefully when he has time available. If any comments are necessary, he can call back the engineer, but initiative is with manager. **(FIGURE 2)**

SIMULTANEOUS QUESTIONS presented without necessary related information can cause confusion. A memo may be satisfactory to answer a specific question, but it hardly contains enough information for an important decision. A manager's decision can be quite different when he has complete, detailed information and is not pressed into exercising snap judgment. **(FIGURE 3)**

plication has reason to anticipate a question from his supervisor. Test results on the pump in question, related computations and customer data might serve to back up the recommendation to the point that the question is satisfied without discussion.

In some cases the engineer knows that his project report, if satisfactory, will probably be sent by his supervisor or manager to the next level of the organization or to another part of the organization as general information or for further approvals.

Presentation does not require an interview

A completed work project should be a package so self-explanatory that an interview is not required at the time it is delivered to the manager. The manager who receives a completed work project can read and digest its contents in private, at leisure, and without pressure. Then, when he has had a chance to consider the project, he can ask specific and probing questions. How often is a manager forced to appraise work too quickly by a subordinate who is waiting for instantaneous reaction? When incomplete work is presented, it is generally accompanied by a rambling account and a request for immediate appraisal.

When completed work is delivered, only two possible dispositions are possible — acceptance or non-acceptance. If it is not completely acceptable, it is returned with written or verbal comments which may incorporate suggestions and criticisms. The engineer would then be reassigned to the project for redevelopment. Rework would follow the same procedure as the original project.

Manager and staff both benefit

The result of a completed work policy should be better work. Each individual is thrown back on his own resources and is forced to use more imagination. People learn that "pride of workmanship" can exist in engineering work as in the crafts. Of course, better work might be expected, since a manager, freed of the constant inquiries of his subordinates, has time to plan assignments, set organization goals, and study the characteristics of the members of his staff. The completed projects provide an excellent basis for evaluation of performance.

It is true that this discussion is a slightly idealistic condensation of a complex relationship, but the methods outlined can be used successfully to promote more effective manager-staff cooperation, relieve a manager of routine discussion and make it possible for him to more easily recognize his most capable employes.

The individual who really gains most from a completed work policy is the capable engineer. He learns to accept responsibility, to organize his thinking and to make decisions. In completed work, he can show his manager and his company what his capabilities really are. He develops himself through project responsibilities until he has demonstrated, beyond doubt, many of the important qualities required for a more responsible role. Less capable individuals also benefit, since they will also find themselves required to accept responsibilities that bring out their best qualities. If you are a manager, a completed work policy could help your department.

New Capacitor Trip
Operates On Low Voltage

by **CARL FELDMAN**
Boston Works
Allis-Chalmers Mfg. Co.

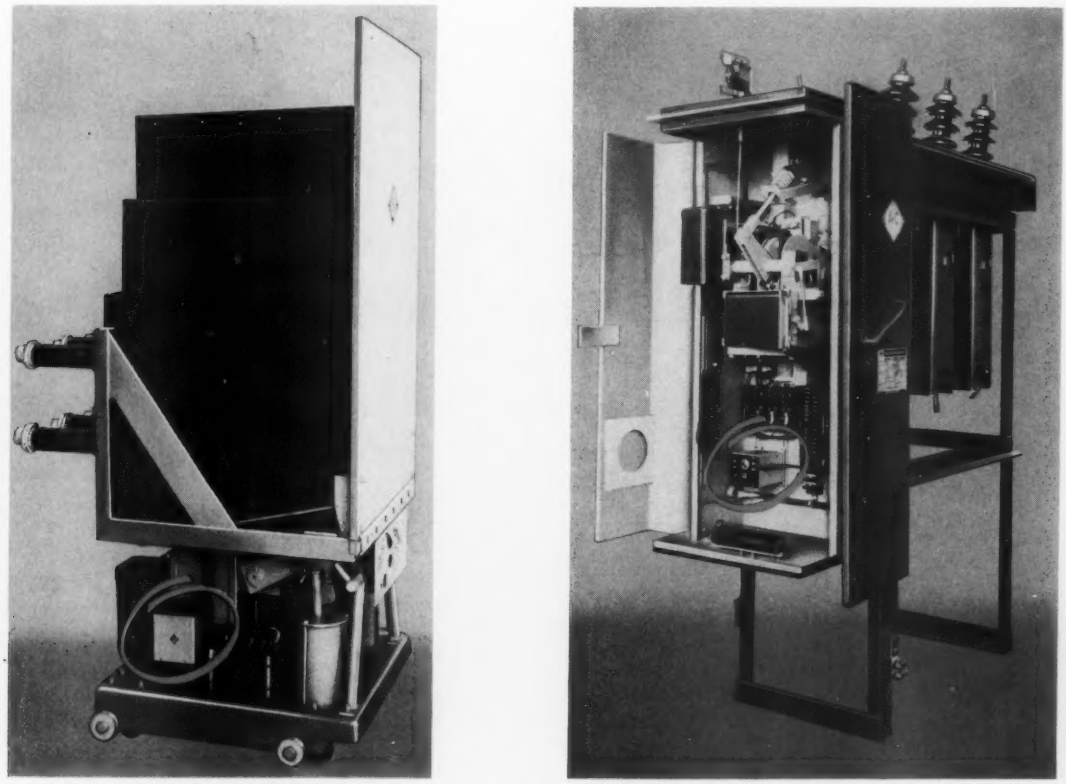
Capacitor trip device operates at normal station voltage and is small enough for installation in limited space.

A DEPENDABLE SOURCE of stored energy for tripping circuit breakers has become increasingly important with the increased use of remote and unattended electric power substations. Adequate tripping power must be available at all times, leading to a desire for other than the conventional storage battery source to minimize maintenance requirements.

The conventional method uses the energy stored in capacitors charged by power from station control circuits. Energy stored in the capacitor from the power line can be used to initiate breaker tripping, even though line power has been interrupted, by discharging the capacitor into the breaker trip circuit. Conventional capacitor trip systems, employing 600-volt inert oil-filled capacitors charged at 500 volts, have proven reliable and adequate when operated within their design limits.

Operating and maintenance engineers have felt, however, that a 500-volt capacitor trip circuit was not desirable on switchboards where all other control circuits are at normal 115 or 230 volts. A few installations with the 500-volt capacitor have been made for operation at 230 volts by increasing the capacitance. Since the capacitance of the 500-volt units must be increased four times to assure dependable trip circuit power for operation at 230 volts, this application has been limited to installations where an unusual amount of space was available within an enclosure, or where the capacitor trip unit could be mounted remotely with respect to the switchboard or circuit breaker.

The capacitor trip device shown in Figure 1 provides dependable operation at normal station control voltage in a minimum of space. The device includes a small 400-



CAPACITOR TRIP DEVICE is easily installed in the cabinet of the small outdoor oil circuit breaker at the right and on the operator of the air-magnetic circuit breaker at the left. **(FIGURE 1)**

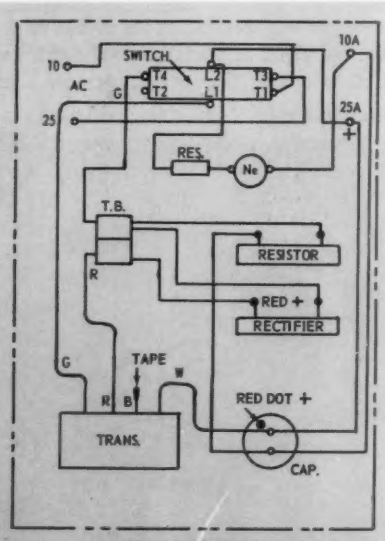
microfarad electrolytic capacitor of high quality which packs much more power in less space than the 50 microfarad capacitor in the 500-volt unit. More trip energy is available from the new capacitor trip device at 115 to 230 volts ac or 230 volts dc than is available from the old 500-volt unit.

A capacitor trip device energized from the same power source used for a control circuit is particularly desirable. For example, a low voltage capacitor trip device can be used to advantage to trip the circuit breaker on the line side of a transformer feeding an electric furnace, in the event of a fault, with the capacitor trip unit on the breaker being charged from the 230-volt furnace control system. The control system power is 230 volts dc, generated by a rotating machine. A battery supply is not available. The low voltage capacitor trip device has proved to be ideally suited to initiate opening the line circuit breaker in the event that furnace control power is lost.

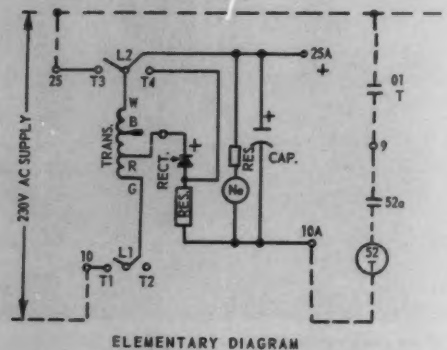
There are several practical low voltage capacitor trip schemes. Figure 2 shows wiring and connection diagrams for a system used for indoor and outdoor circuit breakers that operates on 115 to 230 volts ac. Figure 3 shows diagrams for a switchgear installation with a 115 to 230-volt ac control circuit. A third type of trip control, used for 230-volt dc operation, is similar to Figures 2 and 3 except that the autotransformer is omitted. For 115-volt dc operation, additional capacitance may be required to assure adequate energy for positive trip.

The new capacitor trip device will function properly for the life of a circuit breaker under normal conditions. In the brief time of 10 to 12 cycles of applied ac station control power, the capacitor is sufficiently charged to operate a circuit breaker trip coil. On dc station power the time for an equivalent charge is but slightly greater. Even if station control voltage is reduced to half normal voltage, the capacitor trip unit will be charged sufficiently to initiate normal tripping of its circuit breaker. In the event of failure of station control power, the capacitor will retain sufficient charge to trip the breaker for longer than one minute.

The new capacitor trip device is a dependable source of energy to initiate circuit breaker tripping at normal station power voltage. Its small size makes it particularly advantageous for installation in the limited spaces usually available in switchgear and in the operating cabinets of distribution circuit breakers.

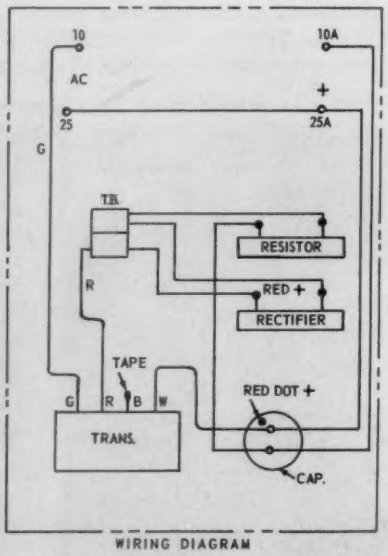


WIRING DIAGRAM

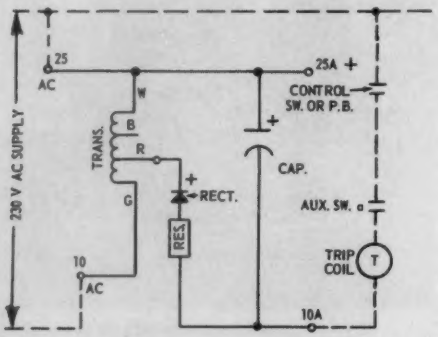


ELEMENTARY DIAGRAM

CAPACITOR IS CHARGED through rectifier when ac source is connected to terminals 10 and 25 with toggle switch "on." Autotransformer steps down 230-volt supply to provide about 155 volts ac, or peak of approximately 215 volts dc at capacitor. Trip circuit is connected across 10A and 25A. Manual control switch or protective relay discharges capacitor through trip coil to trip breaker. **(FIGURE 2)**



WIRING DIAGRAM



ELEMENTARY DIAGRAM

NEON LAMP AND TOGGLE SWITCH are not required for this capacitor trip unit, normally installed within switchgear. The neon lamp and toggle switch would not be visible. **(FIGURE 3)**

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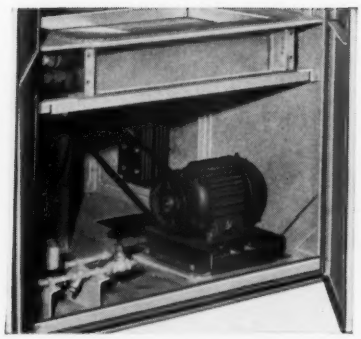

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